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# The renewable energy: Tidal energy

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**Abstract.** This paper discusses the mechanism and principles of tidal energy. As a renewable energy, tidal energy generates electrical power using the potential difference of tides, in which the turbine functions crucially. Through systematic grid integration, energy generated can be efficiently collected and transmitted for practical use. Implementing tidal power programs will bring socioeconomic benefits, whereas environmental degradation and ecosystem imbalance can also be negatively affected.

**Keywords:** renewable energy, tidal energy, tidal ranges, ecosystem, sustainable development.

## 1. Introduction

According to BP USA, world energy consumption skyrocketed in the recent decade and reached an increase of 5.8% in 2021. [1]. While traditional fossil fuels can no longer supply the world's energy consumption and have caused severe environmental problems, engineers focus on renewable energy. This energy source naturally refills on a reasonable timescale and has high sustainability. Renewable energy supplies 20% of global energy consumption, and renewable energy capacity additions expanded by more than 45% from 2019 to 2020 [2]. Studies also suggest the technological and economic feasibility of a global transition to 100% renewable energy in the future decades [2].

Tidal energy is a renewable energy source generated by the water surge created by rising and falling tides. Compared with other renewable energy sources, tidal energy has a high-power density and is predictable over long timescales. In the 20th century, engineers started developing tidal generators to harness tidal energy and generate electricity in areas of significant tidal range. The first tidal generator was constructed in La Rance, France, and Sihwa Lake tidal power station is the largest tidal power plant. However, tidal energy is still in the early development stage worldwide, and the United States has not started largely commercializing tidal energy. More research on tidal power integration, system generic modeling grid code, and environmental effects are needed to explore the further potential of tidal energy.

This paper reviews the history, system physics, system integration into energy grids, economics, and environmental impacts of tidal energy. Future integration applications and economic prospects will also be mentioned.

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## 2. History

More than 1000 years ago, Europeans started using tidal energy to motivate grain mills. The inflow tide is retained in the reservoir, and the outflow tidal motion is used to turn the water wheel to grind grain. This method of generating electricity by falling water and rotating turbines was invented in the 19th century. Early tidal power plants attempted to use a barrage-like approach. However, this did not eventually become the focus of the industry. By the 18th century, there were 76 tidal mills in London alone. There was a time when about 750 tidal plants were operating along the Atlantic coast. Among them, there are about 300 people on the North American coast, about 200 on the British Isles, and about 100 in France. France's lens estuary is the site of some tidal mills history. Now the lance river has the world's first tidal power station. It opened in 1966. As an improvement of the early tidal mill, it generates electricity at high and low tide [3].

From 1924 to 1977, the US electricity Commission and Nova Scotia lighting and power company, with the US and Canadian governments, conducted respectively four early feasibility research of large tidal power plants in the United States and Canada. All investigations focused on specific geographic locations in the boundary area between Maine and Canada. Although the results on economic feasibility vary, no significant progress has been made.

In 1966, a vast tidal dam was built in La rance, France, and is still in operation. It has a power generation capacity of 240 megawatts (MW). Before 2011, it was the most significant tidal dam in the world. In 2011, a 254-megawatt tidal dam was opened in South Korea. In the past twenty years, the industry has turned to in-stream tidal power generation, placing an individual device or a group (or array) of devices in tidal energy. Founded in 2003, the European marine energy center is the world's largest facility under actual ocean conditions to test and demonstrate wave and tidal technologies. The facility has a large-scale prototype grid-connected test site and a small-scale test site for small equipment, which provides convenience for testing more tidal energy equipment than anywhere else in the world.

## 3. The physics and technology

Tidal energy is captured chiefly during the sea level rise and fall, which is caused by the gravitational effect from the earth, moon, and solar system. The moon and sun's gravitational pull generates something called the tidal force. The tidal force causes Earth—and its water—to bulge out on the side closest to the moon and the side farthest from the moon, which are the high tides and low tides. There are two kinds of ways to use these tides. The first one is the vertical movement of water (the difference in water level), and humans apply the tidal range to capture this tide. The second is the horizontal movement of water (moving fluid), and tidal current devices are applied to capture this tide [4]. A more detailed classification is presented in Figure.1.

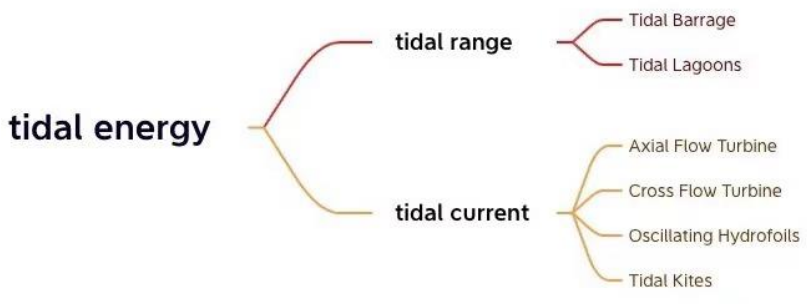


**Figure 1.** Classification of tidal energy.

DOI: 10.54254/2755-2721/7/20230390

*3.1. Tidal range*

The tidal range device uses the water level difference between high and low tides to store water in a basin before being released through the turbine, as illustrated in Figure 2 [5]. Moreover, the turbine rotates using the potential energy of the flowing water. The tidal range devices are mainly applied in shallow water areas.

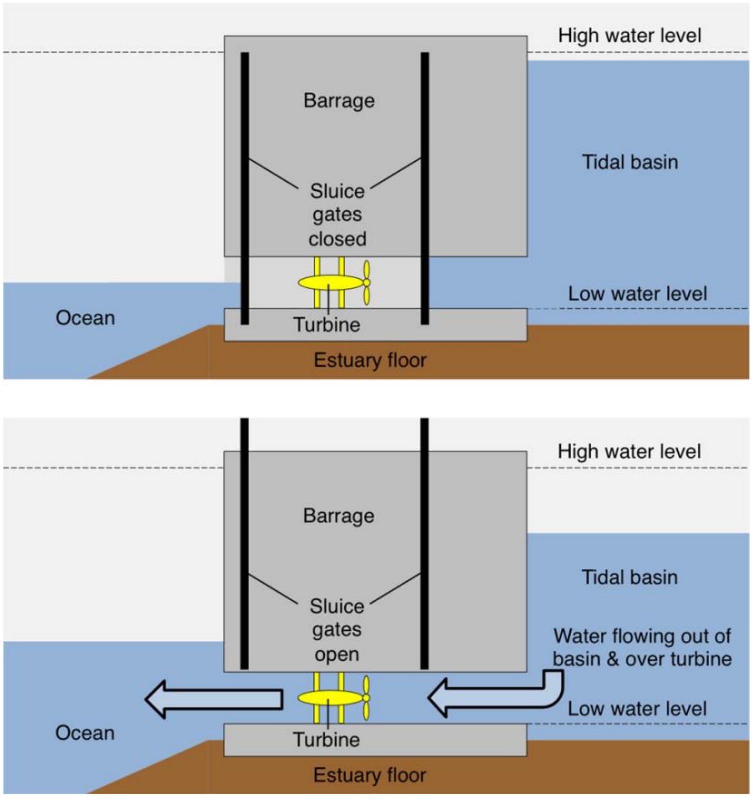


**Figure 2.** Tidal barrage operation. Adapted from wyre tidal energy (2014).

Each tidal range device's potential relates to the difference between high and low head, the amount of water past the impounding structure, and the area of the impounding surface [6]. By considering these factors, a crude estimate of the potential energy available from a tidal range device can be obtained as follows [5]

$$E_p = \frac{1}{2} A_b \rho g H^2$$

Where *E*p is Impounded water potential energy (J)，*A*b is Basin surface area ($m^2$)  *g* Acceleration due to gravity (taken as 9.81 $m/s^2$) ($m/s^2$)，*H is* Hydraulic head (m) *and ρ is* Density (taken as 1025 $kg/m^3$ for salt water) ($kg/m^3$).

By considering some large tidal range devices in some countries like UK, Canada, China, Korea, USA, India, we can get an estimate value of total world tidal range resources to be between 386TWh/y and 560TWh/y.[6]

*3.1.1. Tidal barrage.* One essential component of tidal range devices is the tidal barrage, which works by constructing a wall across an estuary or basin, see Figure 3. When the tide is rising, it is allowed to go through the sluices to the estuary, where the water level is low. And as the water level in the estuary gets higher, the water keeps flooding through the turbine. Then the sluices in the barrage closed. And when the water outside the barrage is low enough, the sluices are opened, which allows

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the water in the estuary to ebb back to the sea. The electricity is generated in these flood and ebb processes with fairly conventional hydroelectric turbines [6].

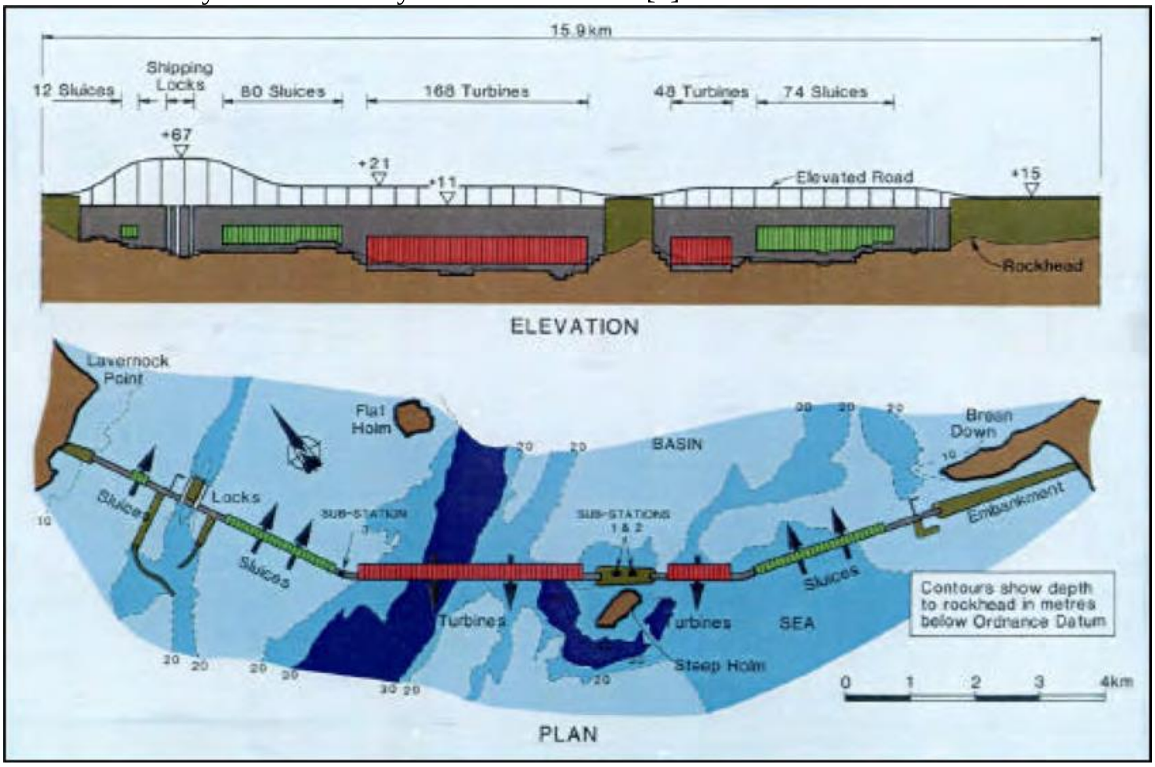


**Figure 3.** Tidal barrage (the Cardiff-Weston barrage, suggested for the Severn Estuary).

The components of a tidal barrage are mainly four big parts, which are a barrage, a turbine(similar to the wind turbine but still different), sluices and an embankment, as illustrated in Fig 2.

a A barrage

A barrage is a structure that is similar to a dam and is built to block water. It usually locates at the front side of a gulf. Moreover, it prevents water from flowing from the low side to the high side.

b Turbines

Turbines, located at the water's passageways, are the main part of a tidal barrage device. They function by transforming the kinetic energy of the flows into electrical energy with a rotating generator.

c Sluices

Sluice controls the entry of the flow

d Embankments

They are caissons made out of concrete to prevent water from flowing at certain parts of the dam and to help maintenance work and electrical wiring to be connected

*3.1.2. Tidal lagoons.* The working principle of a tidal lagoon is somehow the same as a tidal barrage, but there is a difference in the structures. A lagoon consists of an entirely artificial basin formed like a circle or rectangular with a turbine constructed within the walls [5]. Tidal lagoons are illustrated in Figure.4 and Figure.5 below. As with barrages, tidal lagoons hold back water behind the structure and then allow it to flow to the lower levels later. Tidal lagoons also use conventional hydroelectric turbines to extract energy from the water [6].

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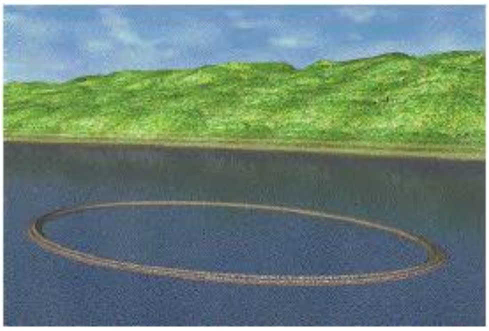

**Figure 4.** Artist's expression of a subtidal tidal lagoon

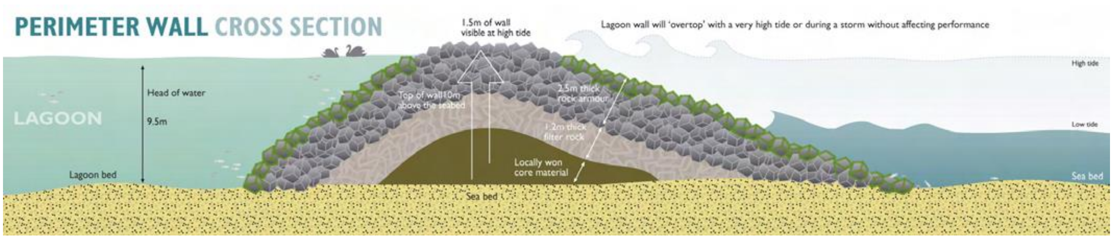


**Figure 5.** Cross-section of a subtidal tidal lagoon suggested for Swansea Bay.

*3.2. Tidal current devices*

Tidal current devices utilize only a portion of the energy from the tidal stream with a rotor placed into the flow (Figure.6) [6]. Tidal current technology use devices to convert kinetic energy into mechanical energy and then to electrical energy, which is somehow similar to wind energy devices. But considering the differences between water and air, such as the density and the flow speed, the tidal current devices have to be designed to survive higher structural load and allow both ebb and flood directions [4]. Tidal turbines can be broadly classified according to their design as either axial flow or cross flow, as illustrated in Figure.7

The power that a turbine can generate from a free fluid flow can be illustrated as:

$$P = \frac{1}{2}\rho A C_p u_\infty^3$$

Where $\rho$ Density (taken as 1025 kg/m3 for saltwater) (kg/m3), *A is* Device swept area (m2), *C*p is Turbine power coefficient (dimensionless), $u\infty$ is Free-stream flow speed (m/s).

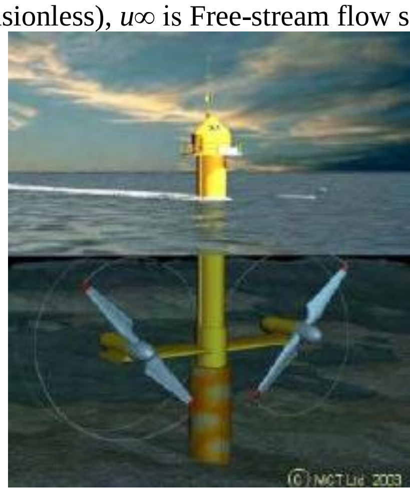


**Figure 6.** Tidal stream turbine.

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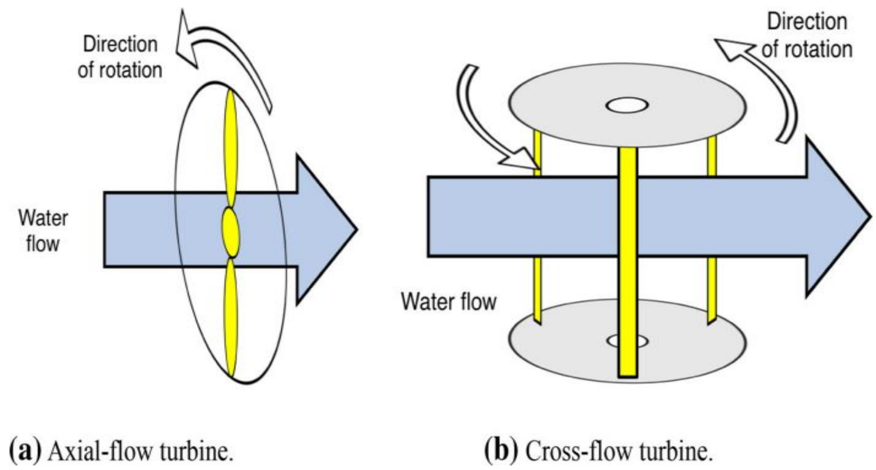


**Figure 7.** Tidal turbine rotor types.

Since the tidal range devices are the main focus and the more promising part in my perspective, I will not specifically introduce tidal current devices.

## 4. System integration into the energy grid

Seas and oceans offer a carbon-free renewable energy source that can be converted into power. This is a huge benefit compared to conventional power plants that rely on combustion. As a result, several nations are considering marine energy as a viable source of electricity to cut carbon emissions and expand their electricity supply.

Grid codes are updated to incorporate ocean turbines' requirements to maintain the power supply's stability and quality. These parameters help create more precise ones because ocean energy has similar qualities. Additionally, the dynamic type mathematical modeling of ocean turbines generally paved the door for the variable power generating units (Figure 8).

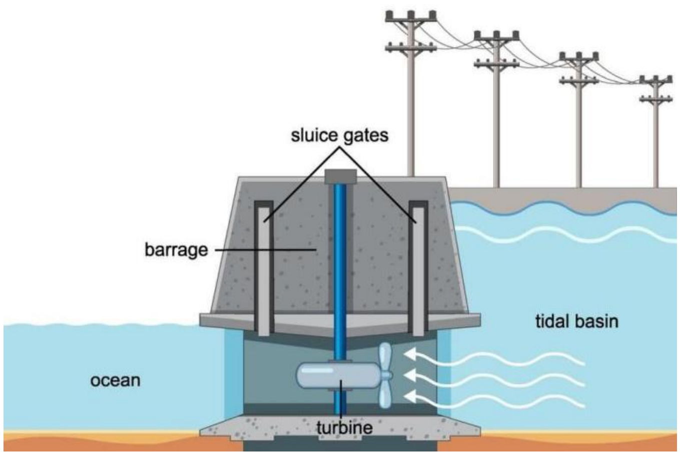


**Figure 8.** Tidal power station and electric grids.

### *4.1. Tidal energy converters*

The type and state of development of tidal energy are incredibly diverse. Ocean energy converters come in several forms. No tidal energy converter concept is now emerging as the leading technology; most of the devices vary from the test stage to the detailed concept design stage, with just a tiny number pre-commercial (Figure 9).

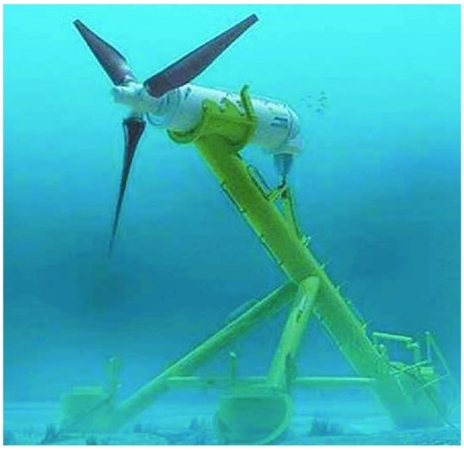

**Figure 9.** Tidal energy converter.

### *4.2. Grid integration of tidal energy*

The biggest problem with integrating tidal energy into the system is power fluctuation. Since there is no agreement on the kind of tidal energy device, the literature presents a variety of tidal energy converter combinations that involve both direct and indirect connections. Due to the resource's unpredictability, direct connection to the grid creates several difficulties that typically call for adopting a storage component. However, output power fluctuations are a standard grid integration issue, necessitating a power electronic conversion system. Tidal power output can adhere to grid rules thanks to the controlled switching of these power converters. As the use of renewable energy in the electric grid increased, energy storage systems have become increasingly important in addition to power converters. Energy storage systems allow for the storage of excess electricity while also enhancing the reliability of intermittent and erratic renewable generators.

### *4.3. Role of energy storage in grid integration of tidal energy*

Tidal energy systems cannot compensate for this power and energy imbalance because they lack the inertia response of traditional bulk generators. To lessen the consequences of unpredictability and intermittency, which are intrinsic to the tidal energy resource, inertia emulation can be carried out by integrating energy storage throughout the grid integration process. Energy storage systems are more crucial now than ever due to the development of hybrid technologies for integrating renewable energy sources. Therefore, by reducing the impact on the power network and offering ancillary services to future grids, tidal energy storage adoption increases this intermittent source.

### *4.4. Energy storage system*

There are many different storage device possibilities, so choosing the right one for this application is crucial. The energy storage system provides output power smoothing, suppresses short-term fluctuations, and aids in frequency and voltage management. Below are three categories of marine renewable energy storage (Figure 10).

- Mechanical Storage Technology
- Electrical Storage Technology
- Chemical Storage Technology

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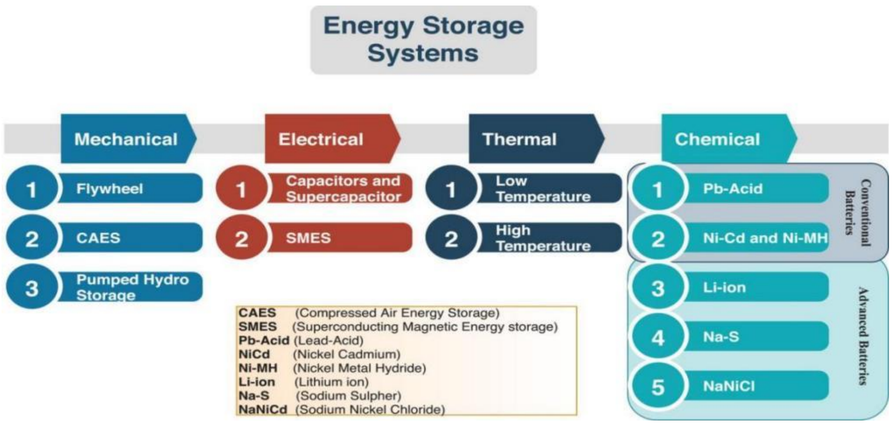


**Figure 10.** Common energy storage systems for grid integration.

*4.4.1. Mechanical storage technology.* Because the storage component is more significant in mechanical energy storage devices, they often have higher power ratings. The figure illustrated the use of pumped hydro storage, flywheels, and compressed air energy storage (CAES) as mechanical storage. Fast response times and high energy densities are necessary for grid integration studies; flywheels, among mechanical energy storage technologies, may be effective for these applications, considering the downside of high self-discharge levels.

*4.4.2. Electrical storage technology.* On the other hand, electrical storage technologies are frequently employed for grid integration of renewable energy sources. These technologies are supercapacitors, capacitors, and superconducting magnetic energy storage (SMEs). Despite their weak self-discharge response, these devices are appropriate for power quality and grid integration improvement applications due to high cycle efficiency and power deliverability.

*4.4.3. Chemical storage technology.* Chemical energy storage systems, which can be divided into traditional and advanced batteries, are the most frequently utilized storage systems in various industries, such as electric vehicles, mobile phones, and others. Lead and acid, Nickle, and Cadmium batteries are examples of conventional batteries that have established technology and are utilized in various applications. Lithium with ion and sodium-sulfur batteries are examples of advanced batteries. The most popular technology, Lithium-ion, is present in practically all battery-powered portable electronics. As a result, they are frequently employed in frequency regulation, voltage management, and integrating renewable energy into the grid.

### *4.5. Grid codes*

Grid codes define the parameter a facility must meet to ensure the safety and proper functioning of the electric system. One of the biggest obstacles to tidal energy grid integration is the lack of grid codes for specific tidal energy devices. No standardized grid codes have been established for tidal energy yet. Most researchers refer to the wind energy grid codes for tidal energy converters; however, this reference is inaccurate without power mitigation. As shown in the Figure.11, there are differences between the peak and average power, and the grid code needs to specify what the word "power" implies. As grid codes limit power ramp rates, a tidal generator's speed increases and decreases power generation. Grid codes cannot pose limits on tidal devices with power output like the one shown in Figure.11.

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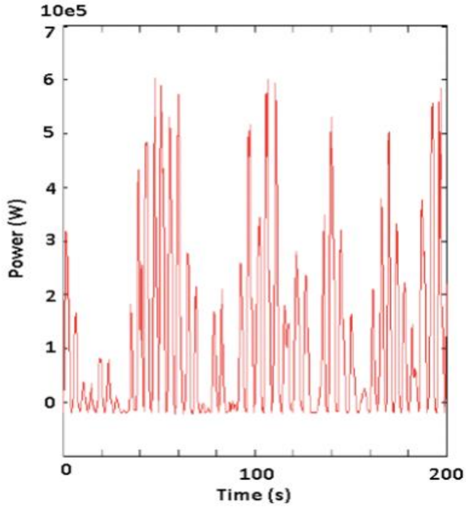


**Figure 11.** Example of the electrical power output of a wave device without power mitigation means.

Grid codes play a crucial role in tidal energy grid integration as power plants with a capacity over 5MW are required to pass the grid compliance before being connected to girds. In conclusion, specific grid requirements should be issued for ocean energy converters based on their power quality and system stability [7].

### *4.6. Tidal technology application comparison*

Tidal energy has significant variability in terms of tidal technologies and implementation methods. However, four standards assess the suitability of common technologies for application in coastal and marine areas: power density, scalability, durability, and maintainability [8].

*4.6.1. Power density.* Power density measures the amount of power a concept can generate for its size. Axial-flow turbines have a theoretical power density of 1kw/m^2 by unbounded flow with speed greater than 1.5m/s, which is slightly higher than cross-flow turbines, shown in the graph below [8]. Both axial-flow and crossflow turbines are suitable for small-scale implementation, such as in shallow water. Unducted turbines have power densities comparable to hydrofoils, and both can generate a relatively large amount of power for their size (Figure 12).

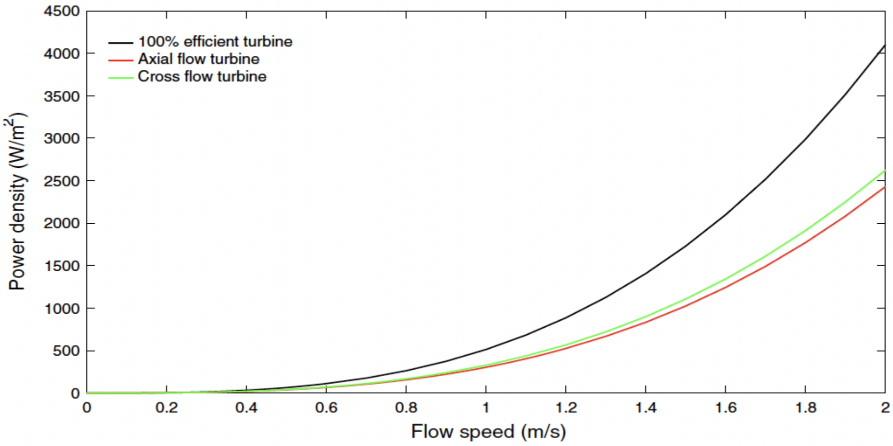


**Figure 12.** The power density of axial flow turbine and crossflow turbine.

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Ducted turbines and tidal kites are not favorable for shallow water implementation. Though ducted turbines generate a roughly equal amount of power with smaller rotors than unducted turbines, their power density is relatively less than that of the unducted turbines considering the large duct construction area. In addition, as tidal kits require a significant installation depth, they are impracticable to be implemented in shallow waters.

*4.6.2. Scalability.* Scalability is tidal devices' ability to increase the size within the limit of shallow water sites. The duct significantly limits the scalability of ducted devices. For example, tidal kites are limited in shallow water as they require a long tether length to sail through the figure-of-eight motion. Tidal range device does not have scalability, not limited by water depth, as their power output depends on the water level differences. Therefore, barrages ad lagoons have greater scalability as they could be constructed on the coastline with a suitable tidal range to reach desirable power output.

*4.6.3. Durability.* Durability is the ability of a tidal device to remain unruined under the potential damage from the ocean environment from corrosion, biofouling, high loading forces, and debris impacts. As axial-flow turbines expose their blades to the ocean environment, they are more susceptible to damage. On the contrary, the blade tips of vertical crossflow turbines are less exposed. Similarly, oscillating hydrofoils also suffer from the problem of damage and biofuels. On the contrary, ducts could protect ducted turbines against damage. Lagoons and barrages are more durable than axial-flow turbines as they are less exposed to the marine environment.

*4.6.4. Maintainability.* Maintainability measures tidal devices' ability to be repaired and maintained. Axial-flow turbines have challenging maintenance as all the generator parts are underwater. To reduce the cost of maintenance, engineers could use more robust materials and construct a geared transmission system to lift the generator out of the water. Vertically oriented crossflow generators have easier maintenance as they enable the generators to be constructed above the water line. Maintaining hydrofoils and tidal kites is generally easier than turbines as their generators could be located above the water for access. The maintenance of barrages and lagoons is also easily accessible.

*4.6.5. Conclusion.* In conclusion, crossflow turbines and oscillating hydrofoils are suitable for shallow near-shore water applications with a high-power density and maximum devise size unconstrained by water depth. In contrast, tidal kites, barrages, and lagoons are the least appropriate for the situation as they require deeper water and more construction investment.

### *4.7. Real-world tidal energy grid integration examples*

Starting in 2000, many countries, such as the US, China, Russia, South Korea, and Brazil, started focusing on tidal energy. Engineers around the world simulated various technologies to be integrated into the grid. Research centers such as the European Centre for Marine Energy (EMEC) in the UK and Fundy Ocean Research Centre (FORCE) in Canada develop mathematical simulation methods to analyze the properties of various power conversion systems. Those grid integration technologies include numerical simulations, Maximum PowerPoint Tracking (MPPT), and Energetic Macroscopic Representation (EMR). A numerical simulation was developed to analyze the economic issues of a tidal power plant on the French Atlantic coast depending on the underwater pumped storage energy. In Iran, the Maximum Power Point Tracking (MPPT) method has created a supercapacitor (SC) to compensate for and manipulate the grid water injection fluctuation. In addition, the graphical formalism tool has been utilized to represent multi-physics systems, and Energetic Macroscopic Representation (EMR) was created in 2000 as the latest graphical formalism tool. EMR has been applied to represent the power conversion system in the Orkney system.

*4.7.1. La rance tidal barrage.* La Rance Tidal Barrage is the world's first and second biggest tidal converter, constructed on the Rance River in Brittany, France. The tidal power station supplies 0.012%

of electricity in France as generated by 24 turbines and a peak rating of 240MW. The tidal power station has a 40% capacity factor, with an average power output of 96MW and an annual output of nearly 600GWh. The barrage is 750m (2461ft) long and ranges from Brebis point in the west to Briantais point in the east. The 24 turbines have a 5.35M (17.55ft) long diameter and a rotational speed of 93.75rpm. The Rance River started with an 8.2m average tidal range and a reservoir of area 184,000,000m^3 that yields a max power flow of 9600m^3/s ( Figure 13 and Figure 14).

**Figure 13.** La rance tidal barrage.

**Figure 14.** La rance tidal barrage structure model.

*4.7.2. The orkney system.* The Orkney System was established by the European Marine Energy Centre (EMEC) to integrate 2MW tidal energy into the energy grid on Orkney Island in England starting in 2003[5]. EC recognized the tidal stream energy of Orkney Island as one of the world's most significant potential tidal sources. The Orkney grid employs Orbital )2 turbines through an energy management system (EMS), as shown in Fig.15. The system control power flow with a control generator side converter (GSC), grid side converter (GSC), and DC link. The turbines have a 16m diameter, 11kv, and 16rpm [9] ( Figure 15).

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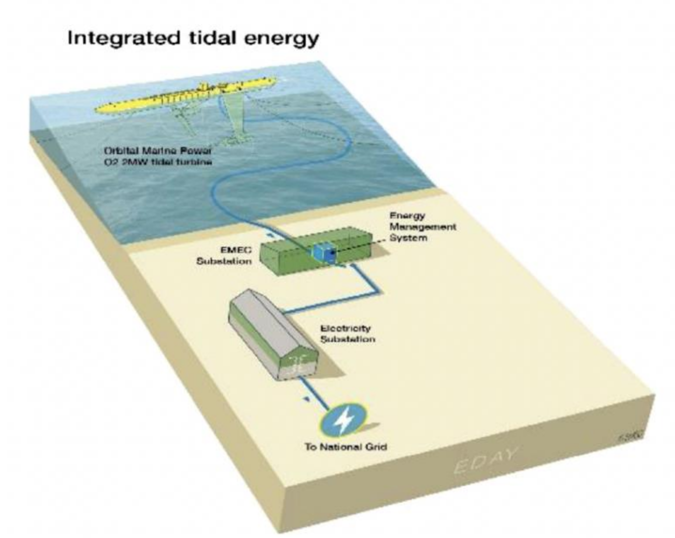


**Figure 15.** The orkney system configuration.

*4.7.2.1. Application of the EMR to the TEC system of the orkney grid.* The EMR system in Orkney Island consists of conversion, source, coupling, and accumulation elements, as shown in the table below [9]( Figure 16).

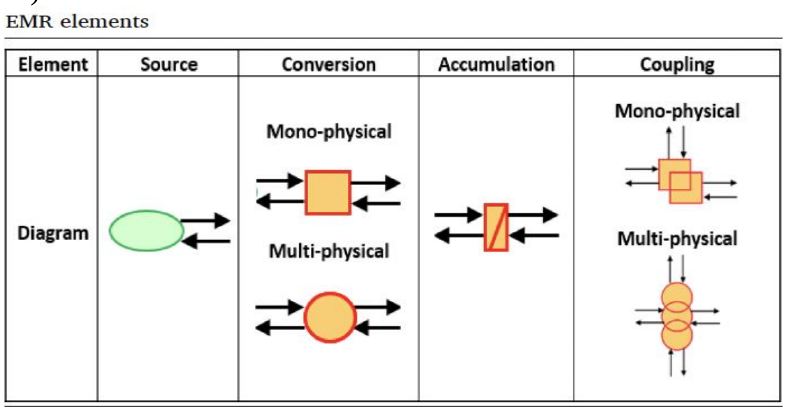


**Figure 16.** EMR elements table.

The tidal energy conversion (TEC) system is integrated into the Orkney grid to convert the water kinetic energy into electrical energy. As shown in the system structure on the right, the TEC chain contains a tidal turbine to convert mechanical and electrical energy, a control system based on a DG-bus step, a three-phase bridge rectifier, and an inverter [9] (Figure 17).

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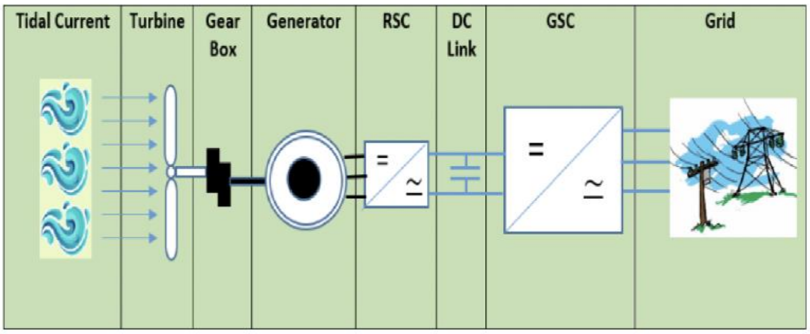


**Figure 17.** Single-line TEC system.

The TEC control is added to the EMR system using the EMR inversion rules. The EMR block diagram of the Orkney system and the structure of EMR application to the TEC system is shown in Figure.18 and Figure.19.

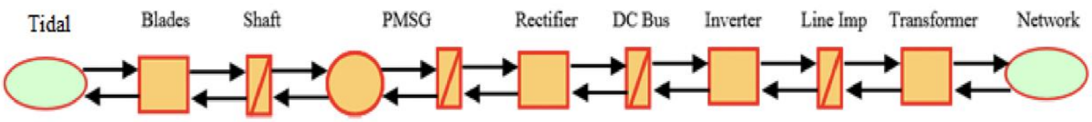


**Figure 18.** Elements of tidal energy conversion.

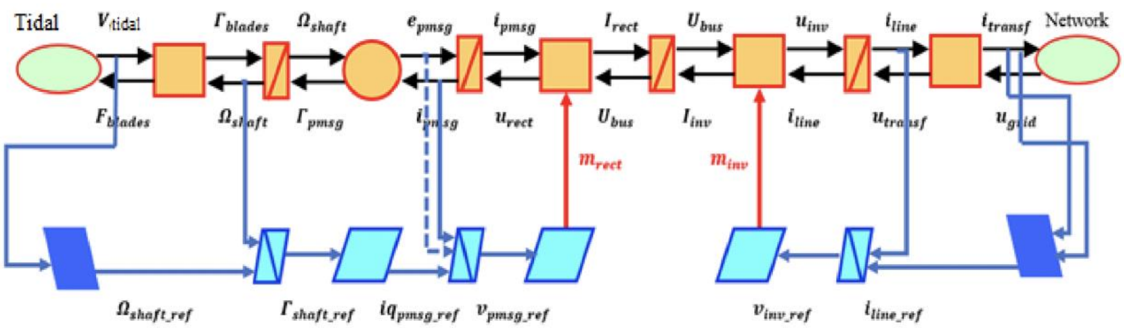


**Figure 19.** Structure of EMR for TEC control.

*4.7.2.2. Power storage regulation in the orkney islands.* Control over turbine power capacity is necessary to reduce the strain on the grid and create a stable energy generation pattern. For example, as shown in the Figure.20 graph below, by regulating the power released per turbine to 21KW, the system can generate a constant 840 kW power supply [9]. The rest of generated energy could be stored in the 2MW/1MWh lithium-ion battery [9].

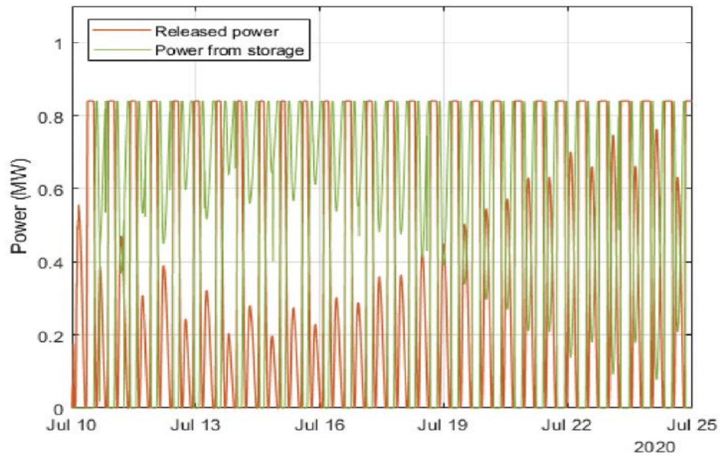


**Figure 20.** Regulated power output of the orkney grid.

## 5. Economics and expectations

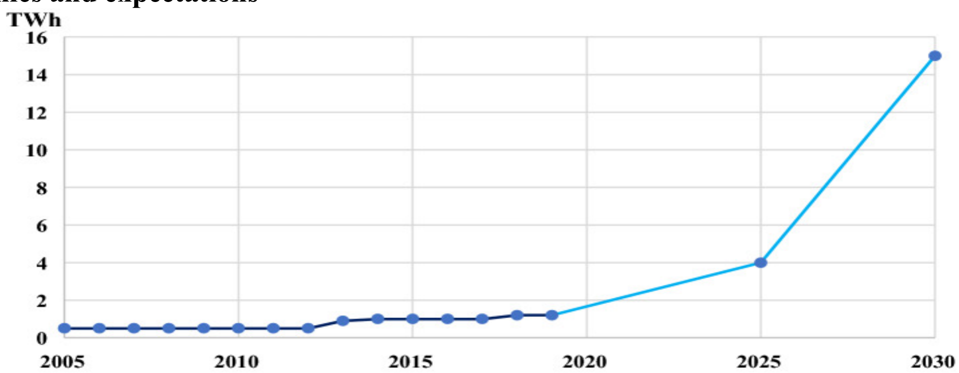


**Figure 21.** Ocean power generation scenario, 2000–2030 IEA 2020b.

**Table 1.** Globally planned tidal power stations（Source: Ko et al. 2019, Newenergyupdate, 15.12.15, EnergyNews, Project, WalesOnline, Tidallagoonpower, BBC, 10 April 2014.）

| **Name** | Garorim bay tidal power station | Incheon tidal power plant | Tuguraskaya tidal power plant | Mezenskaya tidal power plant | Skerries tidal stream array | Tidal lagoon Swansea bay | Gulf of Kutch project | Alderney tidal plant |
|---|---|---|---|---|---|---|---|---|
| **Capacity(MW)** | 520 | 1320 | 3640 | 24,000 | 10.5 | 320 | 50 | 300 |
| **Country** | South Korea | South Korea | Russia | Russia | UK | UK | India | Alderney |
| **Primary Cost($)** | 1 billion | 3.4 billion | - | 22.76 billion | 0.07698 billion | 1.3 billion | 0.15 billion | 0.830 billion |

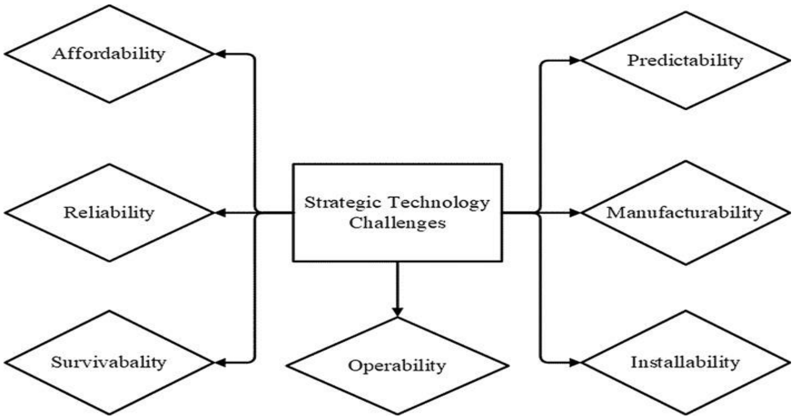


**Figure 22.** Challenges in the development of tidal energy Energy, December 2012.

## *5.1. Prospect*

*5.1.1. Basic statistics.* The economics of tidal power is optimistic. By 2019, because tidal power technology was not yet sophisticated, the gross amount of electricity generated by tidal power was kept at a relatively low level with no more than 2 TWh. For a long time, tidal power generated failed to soar, but by degree, it climbed instead. In 2019, the increase rate of ocean energy was 13%. However, it is anticipated that tidal power technology will show a significant breakthrough in the next ten years that can immensely boost power generation. According to Figure 21, the increase rate of power generation begins to accelerate, and the total amount will double by 2025. Afterward, the power generation amount will exponentially soar from 4 TWh to 16 TWh by 2030. In 2030, the increase rate will attain 23% and even higher.

The significance of tidal energy has been increasingly apparent among all sorts of energy generation. In the future, electricity will constitute nearly 50% of the global energy consumed, and ocean renewable power plants by which oceanic energy is converted into electricity will play an indispensable role in energy generation. However, it was not until 2015 that the global installed capacity of ocean renewable energy, mainly consisting of tidal energy, was 76 million MW.

According to Table 1, many countries are propelling policies supporting and funding the construction of tidal power plants. For example, the United Kingdom, Russia, and South Korea, along with other developed countries whose research on renewable energy are well done, have started costly projects to find power plants that benefit their citizens.

*5.1.2. Economic benefits.* Tidal energy stands out with numerous advantages. First of all, it has the bulk of the energy conversion volume, capable of generating and transmitting a significant amount of electricity at once. Furthermore, it is speculated that a tidal power plant can maintain all local electricity consumption, provided unexpected incidents do not occur. Regarding environmental conditions, neap and spring tides ranging from 4 to 12 m could reach a power of 1 to 10 MW/km, which explains why tidal energy is worth developing [10].

A significant amount of power generation can replace traditional methods like thermal power generation, which burns coals and natural gas. If achieved, adverse outcomes, such as toxic fumes and waste emissions, can be eliminated. Besides, tidal power plants overcome the problem of inadequate efficiency. Traditional power plants consume fuels that only traces of them are converted into available electricity, while the rest dissipate as heat loss. The government's comprehensive installation of tidal power plants significantly saves the cost of electricity generation, presumably leading to scaleable development.

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In addition, tides are predictable, for they are periodic accordingly, following the moon's movement. Therefore, to maximize efficiency, power plant administrators can make rules instructing working schedules, that is, to save the cost in their spare time and to turn up the output power when the tides come.

Building tidal power plants will also boost the local economy. Most power plants are situated in rivers and seasides, where vast lands are required to hold power plants. Coastal lands are expanded; therefore, apart from the occupation of power plants, the rest of the lands can turn to productive farmlands with good water sources. Moreover, power plants urge to recruit employees to run them, reducing the unemployment rate.

### 5.2. Challenges

*5.2.1. Ecosystem impacts.* Although tidal power plants consume clean energy, which imposes little impact on the atmosphere, power plants become a burden on local ecosystems. Because of the enormous power motor which generates electricity by magnets and circuits, a strong electromagnetic field is generated around the power plants. Researchers have found that an unnatural electromagnetic field is primarily liable to affect animal behaviors. For instance, migratory birds, including Canadian geese and the like, navigate by Earth's magnetic field, and so do some fish. Were the electromagnetic field generated, these migratory animals would be puzzled by disturbing magnetic fields and lose directions?

Furthermore, tidal power plants are built over rivers and streams, blocking the river path. Water can pass through sharp spinning turbines, but not fish. Fish trying to swim over turbines are mostly killed and chopped into pieces. That means upstream and downstream are separated into two isolated ecosystems that break fish species' consistency. Migratory routes are cut off, and fishes are restrained within a narrow 'cage,' hopelessly waiting for extinction.

Based on the two drawbacks above, some activists opposed expanding the tidal energy project. In the past, barrages and dams built by governments were later proved harmful to Eco-balance in streams. Due to the breakage of original food chains, certain species overpopulated or depopulated, finally affecting human activities. Taking that into account, governments then decided to demolish those dams, though they had the potential to generate vast amounts of power. Researchers are currently investigating how to reduce environmental harm (e.g., developing a new turbine that is wildlife-friendly) or relocate power plants to minimize the disturbance to the ecosystem. For instance, set generators underneath the sea, avoiding compact layouts to let fish pass them.

*5.2.2. Socioeconomic impacts.* Many cutting-edge research and developments of innovative tidal energy are in developed countries because merely building a tidal power plant costs a 'fortune.' Enormous spatial occupation and power capacity make it a significant expense, highly reliant on capital investment and engineering support. The problem above is affordability, as shown in Figure.22. While the task is demanding, much less developed countries cannot even attempt to manage it. This means tidal power has never been widespread so far unless for a technical breakthrough in the future.

In addition to affordability, operating and maintaining are problems too. Operators must be well-trained to use plant facilities to successfully run the giant machine. Moreover, the dam is fragile when facing natural catastrophes like earthquakes or debris flow. It is even difficult for engineers to reach the dam, not to mention how they can rebuild and maintain it.

It is essential and urgent to develop new forms of tidal energy because traditional tidal power plants are dams that have been proven destructive to the surroundings. In general, floods arise from dams in inappropriate use, which sometimes damage not only natural environments but also residential areas. When floods burst the embankment, most residents near around become displaced due to farmlands and housing being submerged by floods, along with unexpected casualties. Besides that, floods erode downstream soil, taking away nutrients and vegetation. Therefore, people ascribe the damage they suffer to dams and appeal to demolish them, despite dams bringing cheap electricity to local areas. Therefore, it can be seen that dams are not the secure choice to generate electricity with tidal energy [10].

## 6. Environmental impact

The advantages of using tidal energy are apparent. Tidal energy is immaculate energy. There is no waste produced in the process. Of course, the most crucial advantage of sustainable energy is that it is good for the environment. One of the main driving forces of tidal power generation is to cope with climate change by reducing carbon dioxide emissions. It is renewable, reliable, and predictable energy. Compared with diesel power generation, tidal power generation can save about 1000 grams of carbon dioxide per kilowatt hour. Diesel generation power is usually used in remote island communities, with a carbon intensity of 250 g / kWh. When the efficiency of relevant power plants is about 25%, the effective carbon intensity is 1000 g / kWh [11]. Compared with people who use coal to generate electricity, tidal energy has no waste produced. No chemical process like combustion or nuclear reaction is needed to generate electricity. Besides the apparent decrease in the emission of carbon dioxide, tidal energy also can help decrease the emissions of other greenhouse gases like methane and nitrous oxide. Coal, oil, and natural gas combustion produce greenhouse gases. Also, tidal energy has not air pollution emissions like dust or tiny particles such as PM 2.5, which are related to human cancer, cardiopulmonary injury, and mental function: noise and vibration.

To date, few studies conducted to determine the environmental impact of tidal power generation schemes have determined that each specific site is different, and its impact depends mainly on the local geographical location. What has the Netherlands studied so far? There is no underwater acoustic measurement near the existing turbine and the storm surge barrier in the East Scheldt. According to their frequency spectrum, sound source level, and local diffuse conditions, the sound generated by rotating the turbine maybe or not affect the behavior of dolphins. However, dolphins only cross the barrier at low or high tide when the turbine does not move and therefore does not make a sound. If nearby dolphins can hear the sound made by the turbine during rotation, this will add an additional barrier effect or help dolphins locate the turbine to avoid collision with the turbine. In the past, we also studied the noise near the Tokaido turbine of the Dutch landmark Afsluitdijk; On site, the noise from the turbine is almost imperceptible.

Sub hub.

The best solution to minimize the environmental influence is to use the system installed on the seabed to make it far from the water surface and maintain the navigation channel of ships. Moreover, most birds cannot dive the depth [11].

The disadvantages: The influence of tidal power generation on the environment is similar to that of wave power generation and power generation of offshore wind in many aspects. The assessment has identified some potential influences of tidal energy development on the environment. Gill (2005) described some indirect ecological impacts caused by a large number of offshore renewable energy development. These include:

- changes in ocean currents and waves.
- matrix changes, sediment transport, and deposition.
- changes in benthos habitat.
- noise during construction and operation.
- electromagnetic field emission.
- toxicity of paints, lubricants, and antifouling coatings.
- interference with animal movement and migration; and
- strike of rotor blades or other moving parts.

Impacts on biological resources may involve changes in animal behavior, damage and death of some plants and animals, and more significant and long-term changes to plant and animal populations and communities. The development of tidal energy includes technical tests, site features, equipment installation, operation and maintenance, and retirement. The impact of many installations and decommissioning is similar to that of existing industries and is short-term. Therefore, this report emphasizes the impact of tidal energy during long-term operation and the specific impact of installation / decommissioning [12].

The construction of tidal energy stations will influence the environment a lot. When the tidal installation is built, the habitats of the sea life are broken. People must build the station's basement and drill holes under the sea. Moreover, the seafloor will be filled with steel and cement. Also, the waste will deposit on the sea floor in the construction process. After the construction, the sea floor will be filled with waste, steel, cement, and pollution. Sea water is corrosivity, and the force of the current is enormous. So when the station works, the toxicity of the paints, lubricants, and anti-fouling coatings will pollute the sea water and kill sea life like coral. The environment easily influences this kind of little species. These little sea lives are easily killed when pollution enters the seawater. However, these little species are the basement of the ecosystem, so when these species are influenced, the whole ecosystem balance will be broken. Also, the turbines need high speed to generate electricity, and in the process, marine life pass through the turbines, and they are easily hurt or killed. The turbines need to rotate over 3000 rmp for a generation.

## 7. Conclusion

There are more than 1,000 years of history for humanity to research and utilize tidal energy. It can be dated back to the Medieval age when people had already begun to use tidewater to drive the waterwheel. However, the first step toward renewable energy took over 100 years after people built commercial tidal power plants. The foremost tidal power plant in the world is La Rance power plant, which becomes the first successful commercial tidal power plant and, meanwhile, an outstanding model for others to imitate. In the past two decades, various forms of tidal energy have been fully developed so that the configuration of tidal power plants is not restrained within huge factories but more novel and sophisticated devices.

There are mainly two forms of tidal energy: tidal range and tidal current. Due to the principle that tidewater periodically follows the pattern of movements of the moon and sun, the gravitational potential energy can be extracted and converted into electricity when tidewater rises and falls. Barrages like dams or tidal lagoons control the flow of water to rotate the turbine.

Another way to use energy from tidal currents is similar to traditional wind energy. However, unlike big barrages, tidal current generators are relatively small and are usually located on the seabed, catching currents flowing through them and generating power. To achieve this, two types of turbines are used: axial-flow and cross-flow turbines.

Electric energy is transmitted through grid integration, providing steady and immense power output. Therefore, researchers have been trying to optimize tidal grid integration to find the best way to transmit robust and surging current to users.

Tidal energy has exclusive advantages in environmental protection. It does not need any fuel and does not emit any waste. With its massive power generation volume, tidal energy is liable to become the mainstay among all renewable energy sources. However, tidal power plants can negatively affect the ecosystem and cost significant expenditures on construction and operation.

All in all, tidal energy has great potential for further development, going to play a significant role in the future.

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