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TIDAL ENERGY

sustainable eco-friendly and convertible energy

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Abstract– **The purpose of this article is to review the contemporary understanding of tidal energy perspective to the evolving technology of the generation of tidal watercourse power. Geographically, it focuses on all continents of the world and the scope of different reports published on consumable resources of tidal stream energy. These valuations are studied as are some methodical simulations of energy, mining by stream tidal generators.**

Tidal energy is probably one of the existing uncultivated forms of renewable energy. It enjoys the advantage of cyclical, recurrent and substantial water movements that globally affects water bodies, low and high tides. Techniques of accumulating this form of energy are same as a terrestrial hydroelectric power that is already utilized. Because of their location, there would be no emissions. Nevertheless, there are several possible nonentities involved and may be harmful to the marine life and other oceanic processes.

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In order to sustain the tidal energy more effectively in terms of usage as well as development, policies need to be made instrumental. Policies that inspire and boost engagement of the communities and experts in offering insight for production of energy. Also based on the evaluation of discrete conduct driving energy usage rather than efficiency in technology, locally centered sustainability appears the most operational technique for general consciousness for use of energy and tidal energy efficiency.

***Keywords*: tidal energy, renewable energy, tidal turbines, stream, barrage, kinetic energy, environmental impact**

INTRODUCTION

Tidal energy is probably one of the most ancient forms of energy ever used by human race. It is a form of hydropower, which converts tidal energy into electric energy. Tide mills were used by the British, French, and Spanish coasts back in 787 AD. Tides are the rise and fall of sea/ocean water levels caused by the gravitational pull of the moon and sun while tide mills are composed of a storage pond, usually filled by tide/flood coming in through the stream and emptied by outgoing tide/ebb via a wheel. When the earth spins along its axis, ocean water maintains an equal level. This is usually due to earth's gravitational pull and centrifugal force [4]. The tides are brought about by the gravitational effect between the sun and the moon, which causes the cyclical movement of the water in the ocean [12].

Tidal energy/power is predictable, non-pollutant and reliable. Tidal turbines placed under the sea are driven by the sea just like the wind turbines. The advantage is that tidal currents are very much predictable, unlike waves and winds. Tidal energy is vanquished in two different ways; binding the offshore tidal watercourses or constructing a partially permeable bombardment across creeks with a relatively higher tidal range.

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On the other hand, gravitational forces from the moon are usually stronger, thereby disrupting the ocean levels causing a bulge. While the moon revolves around the earth, it causes the bulge to move. Areas of the ocean where bulging is experienced get a high tide. The other areas get a low tide [4].

It's also worth noting that ocean water on the earth's side facing away from the moon also bulges resulting in a high tide. The same principle applies as the earth orbits the sun. However, the resulting tides are smaller. During a New Moon/Full Moon, the ocean tides experienced are much greater. This is known as spring tides. On the other hand, during the Half Moon, the tides experienced are usually not high resulting in lower tides. This phenomenon is known as neap tide [1], [3], [4], [5], [7].

The level of tide is also affected by the distance between the moon and the earth. Periods where the moon is closer (Perigee), stronger tides are experienced. Likewise, periods when the distance between the moon and earth is greater (Apogee), smaller tides are experienced.

There exist different technologies used to harness tidal energy. The first one uses a barrier to hold ocean water during high tide. Turbines located on the barrier are rotated as the water is released, generating electricity. Charlier R. Explains further that the tidal energy can be harnessed through a vertical range in height between the high tide and the following low tide (Tidal range), also the energy can be collected from moving the water due to the kinetic effect which possesses energy in it (Tidal stream). Hence, this is done when a stream of water current flowing is directed to move towards a narrow opening whereby the pressure of the flowing water is increased which makes it easier to trap the power stored in it.

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THE PROCESS

This review evaluates the processes and technologies involved in the generation of tidal energy. Interaction between earth, the sun and moon results into tides. Rising and falling of tides to over 12 meters generates what's called potential energy. Ebb and flood currents flow also to form Kinetic energy. Tidal energy technologies can harvest both potential and kinetic energies as renewable. There are three categories of tidal energy technologies:

A. Tidal Range Technology

Flood tide and ebb tide had to create a different potential energy, which is harvested by the tidal range technologies. This exists in places where large amounts of water are flowing to compounded spaces due to ecological and geological conditions. Since the energy produced here is not subjective to weather conditions, tidal range energy can be predicted. However, cyclical constellations are influential on the resultant energy and the gravity of the moon, earth and sun also have an effect availing anticipated annual, biannual and biweekly cycle.

Most of the predictable tidal range systems work with bulb turbines that are hydropower turbines equivalent, though the latter are mounted in a dam. This technology has various options for the generation of power. One of the ways is power generation at the ebb tide. The pool is filled through a valve that closes when the tide reaches the maximum level. At ebb tide, the reservoir releases water through turbines and as a result power is created. Power is generated four hours every day with a single cycle. Another point where power is generated at the flood tide. Here the stream gates remain closed in order to isolate the pool at the lowest point. The seaside water flows into the pool when the tide is high through turbines, thus producing power. The problem with this setup is that less capacity of power is generated and this is ecologically detrimental as the impoundment water level remains low for quite a long

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time. The third option for creating power is a two way power generation. In this preference, both ebb and flood tides generate power via turbines. The setup cycle produces power four hours two times every day. Though, reversible turbines are essential and a must.

B. Tidal Current Technologies

Tidal current technology translates kinetic energy into a usable form of energy. Developments in tidal current technologies are analogous to the advancement in wind turbines. Most of the large scale growth projects work with horizontal axis turbines, but in three different categories.

Horizontal axis axial and vertical axes cross flow turbines are the first category. Tidal turbines of vertical and horizontal axis currently use blades positioned either horizontally (parallel) or vertical (perpendicular) to the water flow direction. The design of the turbines is similar to that of wind turbines only that they are smaller and are slower due to the high density of water. Besides, they have to endure superior forces than wind turbines.

Reciprocating devices are another category of tidal current technology. They have blades referred to as hydrofoils with a shape resembling that of airplane wings. These airplane wings-like blades moves up and down in relation to the flow of tidal stream on whichever side of the blade. The hydrofoil movement successively converts to a rotation to initiate the rotating shaft for the creation of power. In reciprocating devices, blade length is not inhibited by the depth of water, but requires a multifaceted control structure to correctly pitch the blades. There are also other designs still under development and research stage. The category is composed of devices rotating like screw as well as tidal kites carrying turbines under the wings.

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In the past years, massive barrage systems were the norm in the tidal power industry. But due to their negative environmental impact and inefficiencies, research has led to newer technologies [37]. These are as discussed below.

C. Oscillating hydrofoils

The oscillating hydrofoils use foil propellers which are pushed by the flowing water. Marchuk, G.I and Kagan, B. Explain that the pressure due to the flowing water subjects the flapping propellers into an oscillatory motion. The oscillation results into hydrodynamic forces which compel the flapping into a sinusoidal like motion from horizontal to vertical. The speed of the oscillating hydrofoils is dependent to the velocity and density of the running water. Finally, the oscillatory motion of the propellers triggers the generation of electricity by the turbines [18].

TIDAL KITE

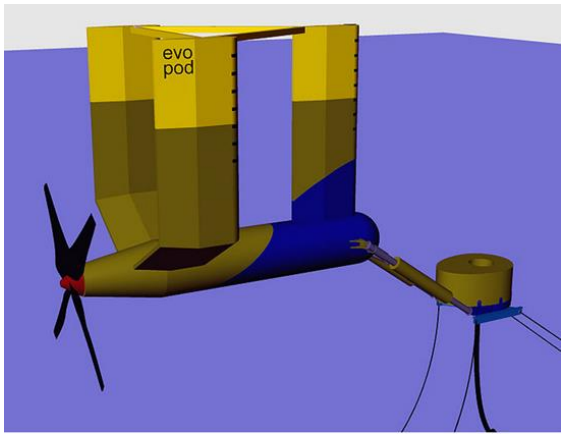

Diagram representing a tidal kite system [20]

A tidal kite is a device placed underwater that converts the tidal energy into electric power by moving in the tidal stream. MCALVANY, D. S., further explains that a tidal kite converts the energy in the tide into electric energy by literally moving through the

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tidal stream and if well implement throughout the world; this device could cater for at least one percent of the world's energy requirements. The other effective devices include Archimedes screws and Venturi devices.

Canada has two tidal plants test sites, one using a tidal barrage while the other uses tidal current. The Annapolis Royal tidal barrage was built in 1984 and has an output of 20MW. The Race Rocks plant built in British Columbia in 2006 uses the tidal current technology. It generates 65kW.Tidal current technology has become the preferred system and soon will replace the old tidal barrages. This is because the tidal barrages have a greater impact on the environment and also much more expensive to construct and maintain.

Tidal currently have a smaller negative environmental impact when compared to the tidal barrage. However, tidal current cannot yet produce as much power as the traditional tidal barrage. For example, barrage power generation station in La Rance, France produces 240MW. Nonetheless, as tidal technology continues to evolve, numerous test plants are being built and sooner they will be able to output more power than the barrage plants [20].

TYPES OF TIDAL PLANTS

There are three different types of tidal plants where energy can be tapped from tidal streams:

i. Tidal Turbines:

This type of energy generation is more advantageous than other forms. Turbines are placed underwater and are totally invisible. Also, they do not create navigation

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problems for ships. Other than being constructed with relatively less resources, they are less detrimental to the environs.

ii. Tidal Fences:

Tidal fences are a type of tidal barrage. Both tidal barrage and tidal fences share various social and environmental concerns. Also, the two enjoy the benefit of the ability to have electrical generators as well as transformers over water.

iii. Barrage tidal plant:

In this type, a barrage or dam is installed, particularly where there is a contracted channel that water is going through with turbines and gates strategically positioned. When the water runs through turbines, a generator that creates electricity is turned on.

EXPLOITING TIDAL POWER PLANT ELECTRIC ENERGY

One of the most crucial areas that must be addressed is where and how to use the electric power created by extraction of energy from the tides. Tides have a cyclic nature and the conforming output power in a tidal energy plant does not correspond as expected with the ultimate activities of humans. Countries where power industry is well established, tidal power usually forms part of the overall power dissemination system. Nevertheless, tidal power is transmitted over a very long distance because such plants are usually located in places where there are high tides which happen to be far from urban centers and industrial areas.

THE EFFECT OF TIDAL ENERGY ON ENVIRONMENT

Tidal energy is one of the recyclable sources of electricity that do not cause emission of toxic gases accountable for acid rains and global warming. Additionally, there is a

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chance that tidal energy could contribute in a reduction in the use of nuclear power because it is associated with radiation risks. Blocking a bay could result to shifting of tidal flows and as a result could affect the aquatic ecosystems negatively. Studies have been taken to evaluate the effect of tidal power on the environment, the results shows that each and every site is distinct and the effect can be determined by the local topography.

WHY TIDAL ENERGY?

Electricity demand fluctuates from day to day on the electricity grid. Tidal plant supply of electricity will not match the current system demand. However, thanks to lunar cycle & gravity, though tidal currents seem variable, can be predicted and relied on. The power of tidal energy can make a significant contribution to the existing electricity structures, which of course have a wide range of sources. Electricity made of tidal energy can dislodge other forms of electricity, especially those created by fossil fuel, hence reducing discharges of acid gases and greenhouse.

TIDAL ENERGY GENERATORS

Currently, there are three distinct ways for getting tidal energy; tidal streams, barrages & tidal lagoons.

This technology uses a tidal stream generator. This machine acts as underwater wind turbines. Flowing water from the tides is used to spin a turbine which spins a generator producing electricity.

Most of the tidal energy generators have their turbines in tidal streams. The turbine is an engine which takes up energy from a flowing fluid while a tidal stream is a tidal

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made body of water flowing at a very high speed. However, the fluid that a turbine takes energy from can be water (liquid) or wind (air). Since water is denser than air, a tidal energy is more prevailing than wind drive. Just like the aforementioned, tides are both stable and predictable unlike wind. Whenever tidal generators are put to use, steady and reliable electricity stream is generated. Because turbines are bigger in size, placing them in the tidal streams can be complex as they can disrupt the tides being harnessed. There could be a severe impact on the environment subject to the turbine size and the tidal stream location. In shallow water, turbines are more effective and more energy is produced. Also ships can freely move around and traverse round turbines. The turbine of the tidal generator moves around slowly and this prevents the marine living animals from being destroyed by the system.

Barrage is also a form of tidal energy producer that uses an enormous dam. In a barrage, the dam is placed low and water can easily tumble through turbines in the dam. Barrages are built across estuaries and tidal river inlets. Just like a river dam binds the river power, a barrage turbine also harnesses tidal power in the same manner. When the tides rise, the valve of the barrage opens up. However, when the tides get so high, the gate of the barrage closes, thus creating a pool also referred to as a tidal lagoon. Then water is released via the turbines of the barrage generating energy at a frequency that only experts can be able to control.

The impact of a barrage system on the environment can possibly be momentous. Land in the interior of the tidal range is entirely disrupted. Also the alteration in the level of water in the lagoon may possibly damage animal and plant life because the salinity lowers in the tidal lagoon. In case of dams across rivers, the fish is either blocked in or out of the tidal lagoon. Additionally, the marine animals are likely to be harmed by the fast moving turbine blades. Compared to the single turbine, a barrage is much expensive

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form of tidal energy. They bring about complex construction as well as more machines, though there is no fuel cost. They also need frequent observation for the purpose of adjusting power output from time to time.

The final form of tidal energy generated is tidal lagoon. It is made in part of an ocean by building a physical barrier. They may possibly be river mouths and have fresh water empty into them. Tidal lagoon functions more or less like a barrage. However, they can be built along an ordinary coast line. In addition, it could help to generate uninterrupted power. The lagoon does the filling and emptying, while the turbines continue to work. Its impact on the environment is minimal though. Construction of lagoons can be done with natural supplies such as rocks. At high tides they would be submerged while at low tides, they would act as sea wall or breakwater. Larger organisms such as shark cannot be able to penetrate through bum animals can swim around and smaller ones inside it. Tidal lagoon power generators produce low energy output.

It involves development of a tidal lagoon. This is oceanic water, which is partly bordered by a man-made or natural barrier. A turbine is placed at the outlet of the lagoon. As water flows out, it spins the turbine which in turn spins a generator producing electricity. One major advantage of a tidal lagoon is that it has minimal environmental impact. Smaller fish are able to swim around the structure with ease [6].

PROS AND CONS OF TIDAL ENERGY

Pros

i. Renewable

One of the main advantages of tidal power is that it is renewable. Renewable energy is considered to be energy emanating from sources that replenish themselves. Such as

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sunlight, wind, rain, tides and geothermal. This makes the power inexhaustible and efficient since it has no limitations concerning its use [19].

According to Taylor J, the tides always flow and ebb due to the gravitational effect, hence it can hardly be tampered with any phenomenon. This ensures a continuous generation of electricity unlike other sources which may record intermittent supply [37].

ii. Green

It is environmentally friendly. This is because it does not produce greenhouse gases as compared to fossil fuels. Greenhouse gas traps heat in the earth's atmosphere, causing the greenhouse effect which leads to global warming. Installation of the turbines does not require intense work on the earth that will leave the land derelict. This helps in preserving the land from massive deformation [37].

Tidal power also helps in reducing our reliance on fossil fuels such as wood leading to less deforestation. In conjunction with that, it has greatly reduced the usage of oil as a form of energy. The usage of oil is fond of massive pollution like spillage of oil tankers in the seas and also leakage during pipeline transportation, which tampers with nature of the environment [2], [6], [11], [37].

iii. Predictable

Tides follow a cyclic pattern making them highly predictable. Being cyclic gives us a sense of security when compared to other energy sources that rely on weather patterns, e.g. solar power, Wind power, and hydro power. The tides also flows towards one given direction, that is, towards the shore, hence, turbines can easily be installed in the areas known to be strong in tidal effect. This makes it so easy and reliable in harnessing the energy [2], [37].

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iv. Protecting coastal areas

Building barrages for tidal energy out in the ocean can also shield coastal areas from stormy weather. The strong walls constructed traps the powerful tides from getting through to the land which lead to property destruction. Therefore, natural hazards like tsunamis are minimized from occurring in prone coastal areas [18], [26].

v. Long life span

Tidal power plants are usually long lasting and require low operating costs. This reduces the cost of electricity. Due to the span, long-lasting and durable supplies of electricity is also ensured hence the constant availability of electricity [28].

Cons

i. Expensive

Since the method employed to generate power from tidal energy is clearly new technology, it is estimated that tidal power will be profitable for commercial use since 2020 and beyond when it already have stable and improved technology in large scale.

ii. Close to Land

Tidal power generation plant is supposed to be erected close to the land. Also, it should be a place where technological and industrial solutions are ongoing. Optimistically, weaker tidal currents can be exploited in a few years' time at a locality further out in oceanic.

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SUSTAINABILITY OF TIDAL ENERGY.

One of the greatest advantages of this energy, according to BRADY, K., is that it's highly predictable and therefore very manageable, sustainable and is generated at minimal costs. The most abundant forms of tidal energy are ocean and dam currents.

A traditional tidal range technology that locks streamed/rivers with dams has some ecological constraints. Artificially closed water bodies have proven that the prices of running/managing them are high. On the contrary, re-opening previously locked water bodies, i.e. those built in the 1950s to 1970s has shown some good ecological benefits. This is due to the development of a gradient that is advantageous to aquatic ecology (brackish water). It also helps in increasing oxygen content.

Environmental impacts of tidal barrage are; stopping fish migration, forced changes of water levels in the area behind the barrage. Reduced salinity caused by low ocean water and reduced ability of currents to carry sediments are also experienced [3].

An ecological monitoring survey sponsored by UNESCO was started at the Kislaya Guba power plant in Russia. The findings there outlined some of the potential risks involved with such tidal plants. Lack of flowing water caused the whole bay to freeze in the winter. The presence of dead mollusks also proved damage to the ecosystem [23].

Tidal technology can also be used for water quantity management while generating electricity. A newer more innovative tidal current technology is currently in developmental phase. Its ecological impacts are seen to be less than traditional methods.

Its turbines are constructed to revolve at low speeds, therefore cannot injure fish and marine mammals. The reduction in tidal ranges can cause lower feeding areas for birds thereby affection the ecology of salt marshes. However, environmental regulators do not have the required expertise to assess the risks. Additionally, baseline data about

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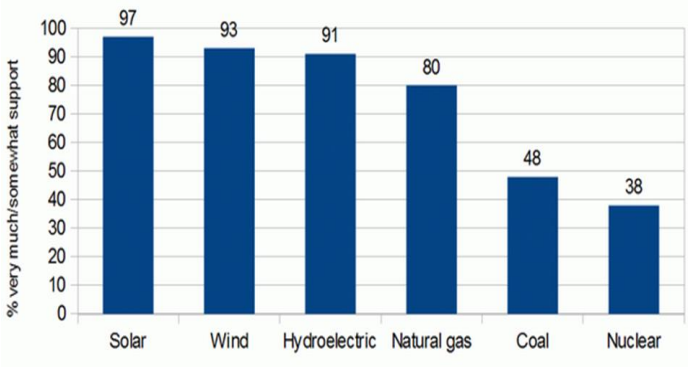
biodiversity in ocean waters is minimal. This results in higher costs for evidence gathering [3], [6].

On the cost of tidal energy, DOANE, W. H., & LOWRY, R., are categorical that cost is more sites specific therefore if the site is convenient for the power generation it would cost less, but if there are complications involved in the initial set up of the site than it could cost more. This cost is in most cases influenced by the distance to the grid used, the volume of the currents, and the speed of the current and the general geography of the site [10].

THE VITAL ROLE OF TIDAL ENERGY IN CARBON REDUCTION.



Eco-friendliness of different electricity generating methodologies [16]

Tidal energy presents a new better form of renewable energy. Based on the success of other similar renewable energy projects such as water, wind and sun, tidal energy has the potential to produce enough energy to tackle climate change. It is also a very clean form of energy basically because its production involves very little production of gases of wastes that would pollute the environment or cause an eyesore.

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Every time fossil fuels are used (e.g. Coal, oil, gas) carbon dioxide is given out into the atmosphere. Naturally, there exists a carbon cycle where plants and trees re-absorb carbon dioxide from the atmosphere. However, the amount of CO2 produced by burning such fuels is greater than the absorption. This causes CO2 to be trapped in the atmosphere. The effect is an increased temperature on the whole planet (global warming), causing changes in climate patterns, floods, hurricanes, heat waves and droughts.

It is with such consequences that the world is changing to renewable sources of energy. Tidal power is likely to succeed as a source of carbon-free, predictable and renewable energy [40].

CONCLUSION

Analytical mock-ups have provided discernments in terms of generation of tidal stream power within the tidal channel. It should be comprehended that tidal energy is one of the extreme deals denoting to power apprehended from activities and effects of tides. Any energy that is netted from currents that is non tidal is definitely linked to tidal energy, except when the current flow is greatly subjugated by the sensation of tides.

In spite of the fact that sustainable energy emits little carbon dioxide, they are dependent on the natural environment in one way or another. Consequently, they are susceptible to climate change. On the other hand, tidal power is rarely affected thus making it a better source. Although this industry is rapidly developing, it will need to address potential environmental risks in order to achieve clean energy.

This review evaluates the potential of tidal energy. It has also assessed various aspects of tidal energy for healthier understanding of technology. So far, it is now clear that tidal power is one of the cleanest renewable sources of energy, though not fully explored.

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Accessibility and environmental impacts are limited there are higher probabilities of it becoming one of the most reliable electricity providers. In places where tidal energy is worthwhile, it might be possibly expensive; however, in the long term, it is economical and things will improve when technology gets better. Tidal energy has the probability making a sustainable large scale power supply in various parts of the world where it has been implemented as well as prospective areas looking forward to embracing the tidal energy technology. Also, tidal streams seem to be the best and the most striking method for generating power from tides for the reason that it has less impact environmentally and ecologically. Tidal streams are also less expensive and easy to install. This is a technology option worth investing in.

Meanwhile, there are issues related to tidal energy still under research and development stage. With improvement in technology, all the issues will be addressed. Numerical and analytical tidal energy extraction models require field data as well as scale for assessment, especially in terms of power, output and reliability.

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