



## Reflections on the Implementation of Tidal Energy in Ecuador



Edison David Morillo Tipan <sup>a</sup>, Genial Belvinel Epeni Tombo <sup>b</sup>, Wilson Quijije Castro <sup>c</sup>,  
Roddy Valentin Montes Garcia <sup>d</sup>, Kelvin Stalin Velez, María Rodríguez Gámez <sup>e</sup>

Article history: Received 20 June 2017; Accepted in revised form 22 November 2017; Approved 29 November 2017;  
Available online 22 December 2017

### Correspondence Author <sup>a</sup>



### Keywords

*Environmental impacts;  
Manabí;  
Potentials;  
Renewable energy;  
Tidal energy;*

### Abstract

Renewable energy is a topic frequently discussed due to the need to change the forms of generation, from the centralized to the distributed form and take advantage of the potentials that are scattered in the territory and use local resources and thereby diversify the schemes of distributed generation that allows the man in his daily work to pass from consumption of energy to generator, in this way the environmental impacts are reduced that today accelerate the change of temperature in the planet, noticing in recent years the oil and its derivatives are responsible for this phenomenon. The objective of the research is to reflect on tidal energy, knowing that the province of Manabí, is the one that has the largest coastal area and where there is a potential that can be studied for future use.

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<sup>a</sup> Universidad Técnica de Manabí, (Ecuador/South America)

<sup>b</sup> Doctorate Program, Industrial Engineer, Universidad Tecnológica de la Habana

<sup>c</sup> Universidad Técnica de Manabí, (Ecuador/South America)

<sup>d</sup> Universidad Técnica de Manabí, (Ecuador/South America)

<sup>e</sup> Universidad Técnica de Manabí, (Ecuador/South America)

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## 1. Introduction

A man with the use of oil and its derivatives is causing great damage to the planet with the emission of polluting gases that cause temperature changes. Climate change has had several notable effects and proven by the scientific community, has seen a significant reduction in glaciers, ice in rivers and lakes are reduced over time. The flora and fauna have also been affected by many species need specific climatic conditions, such as temperature and rain patterns to survive. Some of them are forced to migrate to unusual places and wreak havoc on ecosystems.<sup>1</sup>

Three-quarters of the planet's surface is covered by seas and oceans that constitute a huge deposit of renewable, clean and non-polluting energy, but the great costs involved in the installation of tidal power plants slow down the proliferation of energy exploitation. On the surface of these, the winds cause the waves that can reach up to 12 meters in height, also at 20 meters below the surface to see the temperature differences that cause currents; finally, both on the surface and in the background, the conjugation of the solar and lunar attractions, the movement of the waters of the sea, can produce an energy that is transformed into electricity in the tidal power plants.<sup>2</sup>

The marine energy has a considered potential, being able to be one of the sources of sustainable energy that manage to be used in the places where there are coasts since it only depends on the gravitational attraction of the moon and the sun. This type of technology that takes advantage of the natural energy of marine currents, this has already been exploited in France in 1966, with its tidal power plant, this uses the potential energy of the tide being successful in its use. We can also exploit the kinetic energy of strong tidal currents to generate electricity using a tidal turbine, such as wind turbines can be seen to use the wind as an electric power generator. Tidal energy is not economically viable since it is very expensive to carry out one of these plants. This research reflects on the advantages and disadvantages of making a plant that exploits marine energy in Ecuador.<sup>3</sup>

The electricity obtained from tidal energy requires large engineering projects, are considered gigantic turbines, whose movement transfers its power to electric generators through which it is distributed abroad;<sup>4</sup> However, although this is a general concept, there are three different methods to obtain tidal energy that are used in different parts of the world, these can be stated as: Construct a dike in the inlets of the sea, such as bays, fjords or estuaries, that retains water through a system of gates, in periods of low tide in which there is a difference in height between one side and another of the dam, the water is released through the turbines, whose rotation creates energy.

It can also be produced with the use of generators with propellers located under water, which rotate due to the thrust of the marine currents, are similar to windmills, but in this case they take advantage of the kinetic energy (generated by the movement) of the sea; Tidal energy is obtained through dams of great length in which a large number of turbines are disposed, in this case, no agglomerations of water are created and then released, as in the dikes, but the passage of currents in a sense and another to move the propellers of the generators.

## 2. Research Method

To carry out the research, the deductive method and bibliography review were used to interpret the studied problem and reach the expected results. In addition, the *hypothetico-deductive* method was used by observing the behavior of the energy potential in the Manabitas coasts. To check these methods, scientific articles, lectures at international conferences, seminars, monographs and theses among others were reviewed.

### 3. Results and Analysis

#### Environmental Effects of Tidal Energy

This energy is appreciated for its contribution to the reduction of the ecological footprint, however, there are many other considerations and aspects that have been studied around the world in relation to goodness and its impact on the environment.

Studies carried out in South Korea predicted environmental damage such as the reduction of the area between the low tide and high tide limits, degradation of sea water quality and destruction of marine life that would be generated by the controversial construction of the plant. tidal energy in Garolim Ba.<sup>5</sup>

In the UK, usually small physical impacts have been determined, but potentially they could have significant effects on sediment erosion and transport rates, which in turn could have an impact on energy production.

Several researchers have been interested in the energy potential of the Severn estuary in the United Kingdom, but many others have focused on the effects on the environment that could be triggered by the use of tidal technology on this site.<sup>19</sup> Some of the studies carried out indicate that the muddy intertidal zone has lost the carrying capacity of organisms in recent decades, especially in the case of birds and the fish population; however, it is proposed that the construction of a dam on the River Severn would induce a large increase in fauna and biodiversity, since it would begin a process of colonization by populations that would move to sterile mud, as well as an increase in the processes of photosynthesis due to bioturbation caused by animal species, which would improve water quality.<sup>6</sup>

The tidal power plants need to be built close to the mainland, which is where the most marked differences between tides occur, leading to a visual impact, occupation of coastal areas. It is assumed that in the future, it is possible to locate them in areas of high seas, in figure 1 we can see the map of the plants that are currently operating.



Figure 1. Tidal central map in the world

Fuente:<sup>7</sup>

This technology, being new in its application in relation to solar and wind, is less competitive, with the resulting energy being significantly more expensive than that obtained with nuclear, thermal or other renewable energy sources. Table 1 shows the countries that have implemented this technology.

Table 1  
Tidal power stations

| Name                | Date commissioned | Tidal range (m) | Reservoir area (km <sup>2</sup> ) | Number of turbines installed | Installed power (MW) | Generation (GWh/año) |
|---------------------|-------------------|-----------------|-----------------------------------|------------------------------|----------------------|----------------------|
| La Rance (Francia)  | 1966              | 8               | 17                                | 24                           | 240                  | 540                  |
| Anápolis (Canadá)   | 1984              | 10.8            | 6                                 | 1                            | 16                   | 30                   |
| Jiangxia (China)    | 1980              | 7.1             | 2                                 | 1                            | 3.2                  | 11                   |
| Kislaya (Rusia)     | 1968              | 2.4             | 2                                 | 1                            | 0.4                  | 3.5                  |
| Svern (Reino Unido) | 2000              | 7               | 250                               | In study                     |                      |                      |

Source:<sup>8</sup>

Pre-feasibility studies for tidal energy generation in the Pacific coast have shown that to connect this region with the National Interconnected System (SIN), it is necessary to analyze different aspects since negative impacts can be generated in the economic development of this region.<sup>20</sup> Part of the country, taking into account that this region has a great wealth of mineral resources and great biodiversity.<sup>9</sup>

Tidal energy is a renewable resource, it is the result of the gravitational fields of the moon and the sun, combined with the terrestrial rotation on its axis, and that causes high and low tides. It is a clean energy that respects the environment, besides being a source of renewable energy, it does not emit any greenhouse gas, but it does demand a coastal space in its application.<sup>18</sup> However, being still in development there are very few examples of true tidal plants and therefore, it is not known what their effects on the environment on the seabed, ocean flora and fauna.<sup>21,22</sup>

The tides are predictable, we know when the high tides will occur and when the sea goes down. By knowing these cycles, it is easier to build systems with the right dimensions, since you can know what power is expected in each case, the turbines used are very similar to those that generate wind energy, both in size and shape, as in the installed power. However they have limitations that differentiate it, they are efficient at low speeds, because water is 1000 times denser than air, it is possible to generate electricity at low speed.<sup>23</sup>

Although there are few examples, the La Rance tidal power plant in France, observed in Figure 2, has been in operation since 1966 and today still produces a power of 240 MW, located in the estuary, with 750 meters in length. Take advantage of the tidal difference of up to 13 meters of French Brittany to produce electricity cleanly, both when the tide rises and when it lowers.<sup>7</sup>



Figure 1. Rance tidal power plant

Source: [www.structuralia.com](http://www.structuralia.com)

This type of energy also has drawbacks among which are the affections to the ecosystem, where animal and plant species are affected, even disappearing around these facilities and also produces shifts of the seabed, also has a negative impact on the Water quality and salinity, affects the landscape by modifying the natural environment due to its size and extension.<sup>17</sup> It is worth mentioning that its construction requires significant economic and material investments to build them, it can also be stated that the amount of energy that can be obtained depends on the range of sea movement, therefore, not all geographic regions are optimal for obtaining a good performance of this energy source.<sup>8</sup>

Modes of operation of a tidal power plant with the reservoir, can operate when the tide is entering (flow) when the tide is coming out (reflux) and in both directions (Flow and reflux), additionally, it can be installed a pumping system of water in non-peak hours to increase the slope.<sup>9</sup> The flow mode consists of the generation of electrical energy when the tide is rising and the water level in the reservoir is lower than the level of the tide; then, the generation of energy is done when the flow of water is from the sea to the reservoir, the reflux, consists of the generation of electrical energy when the tide is descending, so that when the tide is rising, the passage is allowed from the water to the reservoir by means of gates, until reaching the maximum level, to allow then the passage of water through the turbines when the tide is descending and the flow of water is from the reservoir towards the sea. Generally, the passage of water through the turbines does not occur until there is a certain difference between the level of the reservoir and the level of tide outside it.

The ebb and flow mode consists of taking advantage of the rise and fall of the tide, by a combination of the two previous modes. With these modes of operation there are intervals in which there is no generation, because the water levels inside and outside the reservoir are the same, for which there is a double reservoir scheme, in which, in one of the reservoirs only water is allowed to enter, when the level in it is lower than the tide (high reservoir) and in the other only the water is allowed to exit when its water level is higher than the tide and the generators are installed between these two reservoirs in which, depending on the volume of the reservoir and the installed power will always have a difference in level to generate most of the time.<sup>15, 16</sup>

### 3.1 Estimation of available power

The potential energy can be estimated with a parametric model, knowing the characteristics of the tide as height or the main harmonic components, as well as some coefficients that in many cases contain uncertainty.<sup>10</sup> An alternative form is presented to carry out a preliminary evaluation, which consists of selecting the design height, the area of the reservoir and the installed power. By means of a graph, you can estimate the amount of energy that will be produced with this combination. The potential energy of the tide is directly proportional to the tidal range. In the particular case of a tidal wave, it is the difference between the rise in sea level and the level of the reservoir. With equation 1, it is possible to calculate the power of an installation.<sup>8</sup>

$$P = \gamma Q \cdot H \quad (1)$$

Where:

Q → Expense that passes through the turbines in m<sup>3</sup>/s

H → It is the difference in levels between the reservoir and the sea, expressed in meters

γ → Specific weight equal to gravity density per m<sup>3</sup>

Q It can be calculated by the equation 2.

$$Q = A \cdot V \quad (2)$$

→ It is the transverse area of the turbines (m<sup>2</sup>)

V → The average speed in the cross-sectional area of the turbine (m/s).

The speed can be calculated by the equation 3.

$$V = Cd\sqrt{2gH} \quad (3)$$

$V$  → Average speed in the cross-sectional area of the turbines (m/s).

$Cd$  → Coefficient of losses

When the energy changes or enters a system, a part of this energy is lost, due to many factors, such as losses of friction along the trajectory and abrupt changes of section and direction among others, which can be taken into account as an efficiency factor through the relationship between the transformed energy and the available energy. Then, the power equation would be as shown in equation 4 according to [8].

$$P = \eta\rho A\sqrt{2gHA}^3 \quad (4)$$

$\eta$  → Efficiency factor

### 3.2 Advantages of Tidal Energy

Although the exploitation of this technology is not as widespread as others, the projects that already exist have shown some significant advantages of tidal energy such as: It is a renewable energy, tides are available throughout the year, although it is cyclical, so that the same power is not generated constantly; it does not pollute, it is clean and silent turning it into an alternative to take into account to replace fossil fuels in the Manabí coast.<sup>14</sup>

Once the necessary infrastructures have been built, the production of tidal energy is relatively cheap in that the energy source comes from nature, you just have to build dikes, barriers or generators with propellers. The facilities that take advantage of the tidal energy are durable and do not require high investments for their maintenance, it is not dangerous for the population, such as fossil fuel emissions, or nuclear power leaks.<sup>8</sup>

### 3.3 Disadvantage of Mareomotor Energy.

One of the main disadvantages is that it needs large initial investments and it takes several years to build their facilities. As of today, the relationship between the cost of obtaining the energy and the yields obtained is very high; On the other hand, it generates a visual and structural impact on the coastal landscape. For the construction of a tidal dam, it is necessary to build a dam in an estuary that modifies the natural state of the site in which it is located, in addition, it must be taken into account that the tidal range because it is not the same in all the coasts of the world, for example, in the Mediterranean the tide is very low, of about 20-40 cm. On the other hand, in the Atlantic Ocean, the tides can reach more than 10 meters, so that tidal energy is only viable in very specific areas of the planet. It also produces negative impacts on the environment, affecting the flora and the fauna, transforming its natural habitat.

### 3.4. Economic studies

Estimates of the cost of energy from wave energy projects vary widely. The creator of the sea mill, an apparatus similar to windmills, which rotates under water, calculates that its apparatus will produce electricity as small as 0.015 to 0.03 cents. The theory behind this device is that it would work in a similar way to true windmills, but the force in the currents is typically ten times more concentrated than that of the wind. Others estimate that the cost of wave energy is three times the estimate. Since there are still relatively few commercial applications, it will take more time to obtain an accurate assessment of the costs involved.

Another factor that makes calculations difficult is that the specific conditions of the wave at each potential location are different, therefore, they will affect the costs. The column of oscillating

water used in Norway has generated electricity for 4 to 6 cents per kilowatt-hour; if this is a clue, competitiveness is good. As with many of the renewable energy sources based on water generation, also the costs for wave energy technologies are very high at the beginning, with the construction and installation of the appliances, the maintenance is expensive for this type of technologies.<sup>10</sup>

The results of the report have been proven since the same critical points could be obtained through in-depth investigation of the subject. In general, equipment is very expensive but in a world where climate change is becoming more drastic each day, this long-term investment can be very beneficial for the country, since there are going to be more sustainable renewable energy alternatives. The impulse of the use of the energy that the government has wanted to propose still gives reasons to continue looking for sources of energy since the subsidies of gas and oil are not sustainable.

It is imperative that further research is done on the subject, in order to locate the most suitable place on the Ecuadorian coast, where a power plant generating this type of energy can be developed in order to remain competitive in the energy market.<sup>11</sup> It is considered that the use of tidal energy must be encouraged, as well as having the use of all clean or alternative energies, such as solar and wind, among others; the use of water as a natural resource implies taking into account the factors involved, among which can be cited, the influence of the stars that produce alterations in the sea, or also the presence of the winds that produce the waves. The most relevant of the use of tidal energy is that it does not pollute, is clean and can be a source of energy savings.

It is important to note that the issue of global warming is a current issue and one should consider ways to mitigate it. One of these is the search for clean and sustainable alternatives that are environmentally friendly, where the potentials that exist on the Manabita coast can be part of those alternatives. Fossil fuels are the main energy producers in this territory, but it is responsible for the production of air pollution. If attention is paid and the native resources that exist in the territory are studied, one could think of a cleaner and more sustainable future and with this, Ecuador could prepare itself for future challenges, mainly the provinces of Manabí and Esmeralda, where the Ecuadorian coasts are located. Therefore the tidal potential; the most important thing is to make people aware of the efficient use of energy, the use of renewable sources and reduce the use of fossil fuels since it is the main source of energy in the territory studied.<sup>12</sup>

#### 4. Conclusion

Fossil fuels, which today are the main energy producers, are largely responsible for the warming of the earth, the road to new forms of energy use with clean and environmentally friendly energies would help mitigate climate change. The tidal energy would be a pillar in the energetic development of Ecuador and the province of Manabí.

#### Acknowledgements

The author thanks for the lecture that helped to complete the present study on time.

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### Biography of Authors

|   |  |
|---|--|
|    | <b>Edison David</b> , Student in the Engineering degree in electricity, Faculty of Science, Mathematics, Physics and Chemistry at the Universidad Técnica de Manabí.   |
|    | <b>Genial Belvinel</b> , Student in the Engineering degree in electricity, Faculty of Science, Mathematics, Physics and Chemistry at the Universidad Técnica de Manabí.  |
|    | <b>Wilson Quijije</b> , Student in the Engineering degree in electricity, Faculty of Science, Mathematics, Physics and Chemistry at the Universidad Técnica de Manabí  |
|  | <b>Roddy Valentin</b> , Student in the Engineering degree in electricity, Faculty of Science, Mathematics, Physics and Chemistry at the Universidad Técnica de Manabí  |
|  | <b>Kelvin Stalin</b> , Student in the Engineering degree in electricity, Faculty of Science, Mathematics, Physics and Chemistry at the Universidad Técnica de Manabí   |
|  | Ph.D. Strategies and Planning territory Renewable Energy Sources, Universidad Pablo de Olavide, Sevilla, España, Ph.D. In Geography. Associate, Professor, and researcher at the Universidad Técnica de Manabí. It has participated in various international research projects aimed at rural areas using renewable energy sources currently working on studies using GIS to study renewable potential and use in distributed generation |