IDENTICATION OF THE IDEAL SITES FOR MARINE TURBINE IN MADAGASCAR

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ABSTRACT:

Preoccupied by the very weak yet expensive energy production in Madagascar and by the fate of the planet and the necessary collective effort to reduce the CO_2 emanations, we wanted to bring a new source of green energy, still untapped in Madagascar: the marine energy however marines turbines operate using the kinetic energy from water masses set in movement by marine currents. The stronger the current is (elevated speed), the more elevated the energy potential is. The identification of the favorable zones to set up the hydrokinetic turbines will be carried out by modeling the speeds of currents, thus highlighting the best sites. Our objective is therefore to identify the ideal sites for the implantation of projects to install hydrokinetic turbines and to propose methodologies of resolution, in particular, the method of the finite element method in order to achieve a numeric modeling of the currentology of the whole western side of Madagascar, based on the parameters of tides and winds.

Keywords: marine turbine, tide, currentology, speed, Madagascar, finite element

1. INTRODUCTION

Madagascar is located in the Indian Ocean. The island is separated from Africa by the Mozambique Channel, with a distance of 400 km.The islands around Madagascar are: Mayotte and the Comoros Archipelago to the west, Reunion and Mauritius to the east, Seychelles to the north.

The main cities of the west coast of Madagascar are:

- Diego Suarez (Antsiranana), located in the Far North
- Majunga(Mahajanga) in the northwest
- Tulear(Toliara) in the southwest
- Morondava in the west
- And Nosy Be, the coastal island of Madagascar located in the Mozambique Channel

Figure1 : Map of Madagascar [1]

2. METHODOLOGIES

Marine turbines are types of underwater wind turbines whose blades are set in motion by sea currents. They comprise a paddle wheel or a propeller, consisting of blades mounted on a shaft whose rotation drives an electric generator. Their diameter is between 10 and 20 meters. These tidal turbines are intended to be submerged at a depth of 30 to 40 meters in areas with a strong current (greater than 4 or 5 knots). [2]

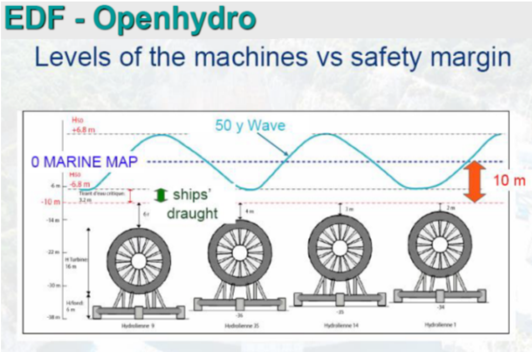

Figure 2 : Levels of the marine turbines under marine [2]

In France, in 2017, the company OpenHydro / Naval Group installed 2 tidal turbines (with a diameter of 16m and a cumulative power of 1 MW) in the demonstration park of EDF Paimpol / Bréhat, bay of Saint Brieuc, [3]

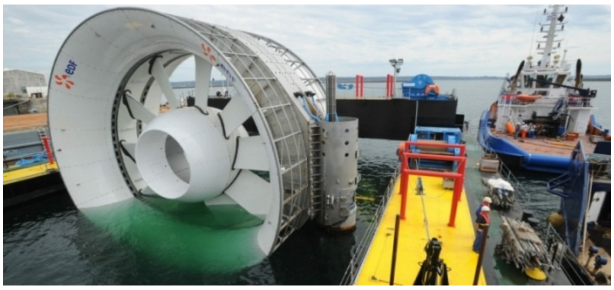

Figure 3 : Hydrolienne OpenHydro

The United Kingdom is the most advanced European country in the field and the UK's Ministry of Energy and Climate's "Marine Energy Action Plan 2010" aims to save 17 million tons of CO_2 by 2030 and 60 million tons by 2050, while creating 16,000 jobs

The marine turbines make it possible to transform the kinetic energy of the marine currents into electricity. There are three main forms of capturing this energy:

- transformation of the kinetic energy of marine currents, including tidal currents encountered near the coast in the case of the marine turbine here treaty;
- use of potential energy related to tidal range (it is the difference of level between full and low tide) by tidal power plants of the Rance type;
- use of wave energy from the wind on the surface of the sea (also-called "wave energy")

The tidal turbines produce energy if the force of the current reaches about 2.5 knots (about 4.6 km / h) and they go to full power beyond 4 knots (close to 7.4 km / h) .

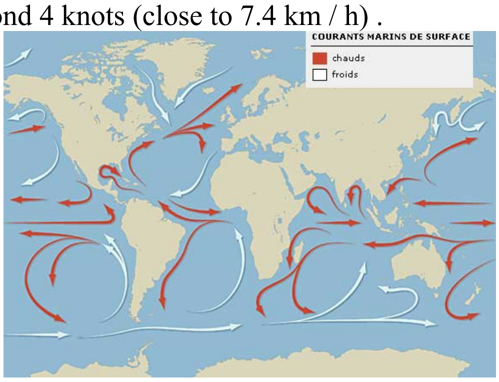

Figure 4: The marine currents [4][5]

On this map, we can see that the warm currents (in red) start from the equator and that the cold currents (in white) start from the north and south poles.

Current of Mozambique: The northern branch of the equatorial current, which bypasses Cap d'Ambre (Madagascar) at a westward speed of 1 to 3 knots, arrives at the coast of Africa at the level of Cape Delgado, located approximately on the parallel of Cap d'Ambre. Part of it changes to the southwest and becomes the current of Mozambique, which runs along the coast of Africa, and whose speed and flow rate change according to the season.

Agulhas Current: The southern branch of the equatorial current passes south of Madagascar at a speed of half a knot, and will join, at the level of Natal, the current of Mozambique. Their meeting forms the current of the **Agulhas**, which can be felt at a distance of 120 miles from the land, and which transports relatively warm waters to the Cape of Good Hope.

This Agulhas current, one of the most violent ocean currents, is also one of the most constant. Along the coast of Natal, its speed reaches 4 knots, sometimes 5, and rarely less than 2 knots.

The identification of the favorable zones to install tidal turbines is thus done by modeling the velocities of the currents which highlights the best sites. The force of the currents depends on the amplitude of the tides, the stronger the current is (high speed), the higher the energy potential is.

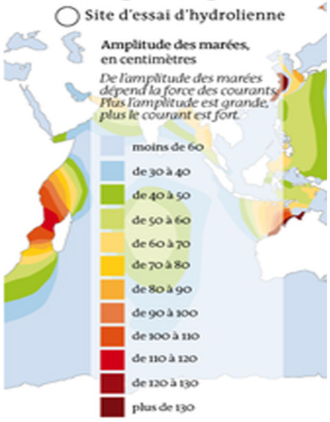

Figure 4 : Potential world marine turbine [6]

The amplitude of the tide has of course an effect on the speed of the current near the coast, and we can consider as a first approximation that the maximum intensity reached by the current during a tide is proportional to the coefficient of this tide according to the formula [6]

$$\vec{V}(hm, C) = \vec{V}_{me}(hm)\frac{(C-45)(\vec{V}_{ve}(hm)-\vec{V}_{me}(hm))}{95-45}$$

C: the coefficient of the tide

hm: the time of the tide

V_{me}(hm) and V_{ve} (hm): speeds

The map of tkhe global potential shows interesting sites around the Mozambique Channel and the west coast of Madagascar between 110 and 120 cm, **where the tides cause strong currents**

3. RESULTS

3.1. Results by researchers

The results by researchers show in particular that in the main cities of the west coast of Madagascar,

- coastal waters are crossed by alongshore currents, the most important of which are tidal currents as well as currents associated with waves that draw their energy from moderate (NW) to strong (SW) winds that are almost permanent along the coasts. The action of these currents is at the origin of accretion phenomena. This is the case in the region of Morondava[7]

Figure 5: Mischief of marine erosion on the coast [7]

Figure 6: Aménagement intégré du littoral [8]

- In a study of the coastal upwelling in southern part of Madagascar (which is a deep upwelling affecting marine life and fisheries), Juliano Dani Ramanantsoa and his coauthors (2018) identified a new coastal current: the South- West Madagascar Coastal Current (or SMACC), it comes from the west side of the island, spreading to the south through a surface current: the SMACC, however, the details of the ocean circulation around Madagascar are still unclear [9]

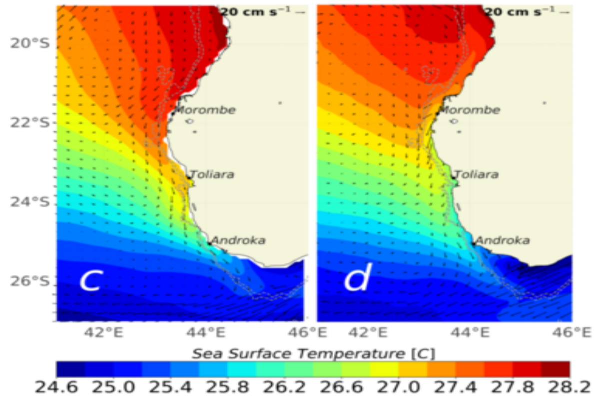

Figure 7: A new marine current along Madagascar

- In an article written by Mandimbiharison Aurélien entitled "Contribution of the cartographic method in the study of the evolution of the coastline of the city of Mahajanga from 1952 to 2015", a part of the beach called "Tourist Village" has been repeatedly modified naturally, not only by its geological instability but also and especially by the effects of **ocean currents and cyclones** [10]

Figure 7: The "Edge of Mahajanga ": the most stable zone in normal times

Figure 8: during the passage of cyclone Hellen in 2014

3.2. Results from our observation

Some village in Morondava is abandoned because of the effects of the marine currents and the villagers put some dams for the protective measure against the coastal erosion

Figure 9: Abandoned village near to the beach

Figure 10: Protective dam

From 13h00 Pm, the navigation in Nosy Be Island is nearly forbidden because the current is very strong but we noticed that the low tide is even present

Figure 9: Waves of Nosy Be Island

Figure 10: Low tide toward 13h00 pm

From these results and other parts, to be favorable for the installation of this tidal energy equipment, the sites must meet the following criteria [11]:

- areas of high tidal currents generating interesting power with a wheel diameter between 10 and 20 meters (current greater than 4 or 5 knots);
- depth of about 30 to 40 meters to limit the difficulties of installation and maintenance;
- proximity to the coast to pull a submarine cable, electrical connection, low cost.

These criteria met by the cities of the west coast of Madagascar, therefore, the projects of installation of tidal turbines are favorable.

In order to follow the movements of the ocean, the laws governing them are:

- The continuity equation

$$\vec{\nabla}\vec{v} = 0$$

- The Navier-Stokes equations

$$\frac{d\vec{v}}{dt} = -\frac{1}{\rho}\vec{\nabla}p + g - 2\vec{\Omega}\times\vec{v} + \nu\vec{\nabla}^2\vec{v}$$

To solve these equations, we will use the finite element method taking into account the geometry of the study area to be meshed and the conditions imposed on the limits of the system:

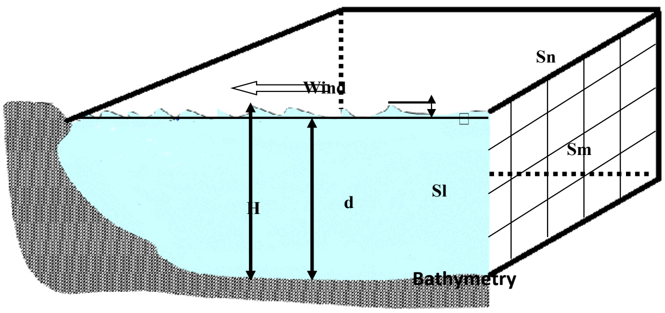

Figure 11: Geometry of the study area

- Bathymetric data from the sea must first be obtained
- At the surface, we take into consideration the wind pressure and the atmospheric pressure acting on the surface of the water

- For the faces S_ℓ, S_m, S_n we impose the conditions of continuity
- On closed borders,the flow equals to zero

We have identified the ideal sites for the implantation in Madagascar but further research is still needed, for example we need to obtain the bathymetric and tidal database:

- the height,
- the period
- the pressure,
- wave direction, in addition to measuring currents.

For the protection and the preservation of the environment, we must work with the marine biologists and the local people, and in addition, the modeling of the coast marine is cartography for the researchers and the people who exploit the marine resources

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