Technical Feasibility Analysis of the Patent Ondomotric Energy Generations System With Code BR 10 2016 016119 3 A2

Kelson Mascarenhas Cirne[1*], Gabriel Pereira Ugucioni Rocha[2], Alex Álisson Bandeira Santos[1]
[1]SENAI CIMATEC – Campus Integrado de Manufatura e Tecnologias; [2]Núcleo de Pesquisa, Desenvolvimento e Inovação, Lactec; Salvador, Bahia, Brazil

With the industrial expansion arising from the national development process, and the current global trend towards the search for clean and renewable energy sources, the diversification of the energy matrix becomes vital in the process of renovation and strengthening of energy generating sources to meet the SIN (National Interconnected System). This work presents the technical feasibility analysis of the wave power generation prototype with patent code BR 10 2016 016119 3 A2. The simulations carried out in modeling software to evaluate the constructive aspects of the prototype allowed the analysis of data on the mass of the components, gravity centers, and moments of inertia. Finally, the positive and negative aspects and points for improvement of the project were presented, aiming to raise interest in the topic presented and develop new studies for the electricity sector.
Keywords: Ondomotive. Patent. Electric Sector. Energy Matrix.

Introduction

With the changes characterized by the challenging scenario caused by Coronavirus (COVID-19), where social and environmental impacts have brought behavioral changes, such as social isolation, modeling strategies for expansion of the electricity sector, which are directly linked to the country's economic growth projections, have also undergone major changes [1]. The Decennial Plan report presented by the Energy Research Company (EPE) shows that, after the impacts on economic growth in 2020, the percentages of resumption of economic development are on average between 2.9% and 3% per year until 2030.

Brazil presents itself on the world stage as one of the countries that maintain its energy matrix as one of the cleanest, complying with the guidelines of the Paris Agreement with the new Nationally Determined Contribution (NDC) pledging to reduce its gas emissions by 37% greenhouse effect by the year 2025 and 43% of its emissions by the year 2030 [2]. Sustainable growth strategies combined with the vision of strengthening security in meeting energy demand contribute to the expansion of studies in the national electricity sector. The use of natural resources to diversify the energy matrix, as well as boost investments in renewable energy sources, is promising for large companies in the electricity sector, as well as for new investors in this market [3].

Geographical positioning is also one of the factors that contribute to the development of solutions aimed at diversifying the energy matrix, in which the oceans represent 71% of the surface of the globe [4]. One of the greatest renewable energy potentials on the planet is linked to the oceans with the following distribution: Wave Energy, represented by the surface and subsurface movement of the oceans, estimated at up to 80000 TWh/year; Hydrokinetic Energy, which is related to the movement of ocean currents and tides, estimated at 800 TWh/year; Ocean Thermal Energy, which can be obtained by the temperature gradient existing between the surface and the ocean floor, estimated at 2000 TWh/year; Osmotic energy, obtained by the pressure difference between opposite sides of a membrane, containing fresh water on one side and salt water on the other, estimated at 10000 TWh/year [5].

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Address for correspondence: Kelson Mascarenhas Cirne. Av. Orlando Gomes, 1845 - Piatã, Salvador - BA- Brazil. Zipcode: 41650-010. E-mail: kelsoncirne@jsglobal.com.br.
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Bearing in mind the Brazilian energy scenario and its geographic characteristics, the literary gaps about the application of ondomotive technologies in the national territory, and the studied potential of the oceans, this work proposes to technically evaluate the constructive aspects of the solution designed by the company Hidrobombas of a system of wave power generation, under patent number BR 10 2016 016119 3 A2. The initial prototype presented by the company was modeled in a CAD environment, according to dimensions and original mechanical elements. Based on the CAD model, studies of the functionality of the power take-off mechanism (PTO), the buoyancy of the structure, as well as of the fluid-structure interaction in the presence of typical waves for the Brazilian coast, were elaborated. Thus, it is possible to estimate characteristics such as the range of motion of the articulated elements of the GEO (Ondomotive Energy Generator) and energy generation, as well as its stability against oceanic movement.

Material and Methods

The technical feasibility analysis was performed at Lactec's research, development and innovation center, located in the southern region of Brazil. For the development of this study, a quantitative analysis was carried out with a survey and analysis of experimental data, for the formulation of mathematical models that allow a technical analysis of the chosen technology.

In this article, simulations in System Dynamics software (3D CAD and ANSYS AQWA) are presented to evaluate the behavior of the model with changes in the input and output flows. The analysis of the 3D modeling allowed obtaining physical quantities referring to patent BR 10 2016 016119 3 A2, such as component mass, gravity centers, and moments of inertia. In this way, it is possible to evaluate the stability of the prototype to be developed using the results obtained by computational simulations of fluid-structure iteration.

Results and Discussion

3D Modeling of the Prototype Geometry

The prototype developed by Hidrobombas, which has patent code BR 10 2016 016119 3 A2, contains 22 drums, 12 for the central structure and 1 for the flotation of each of the 10 arms. This nationally developed and patented model resembles the product developed and named Wave Star of multi-body systems that have two prototypes built, the first being located in Nissum Bredning, Denmark [6].

The power take-off system, known as PTO (Power Take OFF), are devices that are part of the sea wave energy converters, among the existing systems, it was adopted directly (Figure 1) [7].

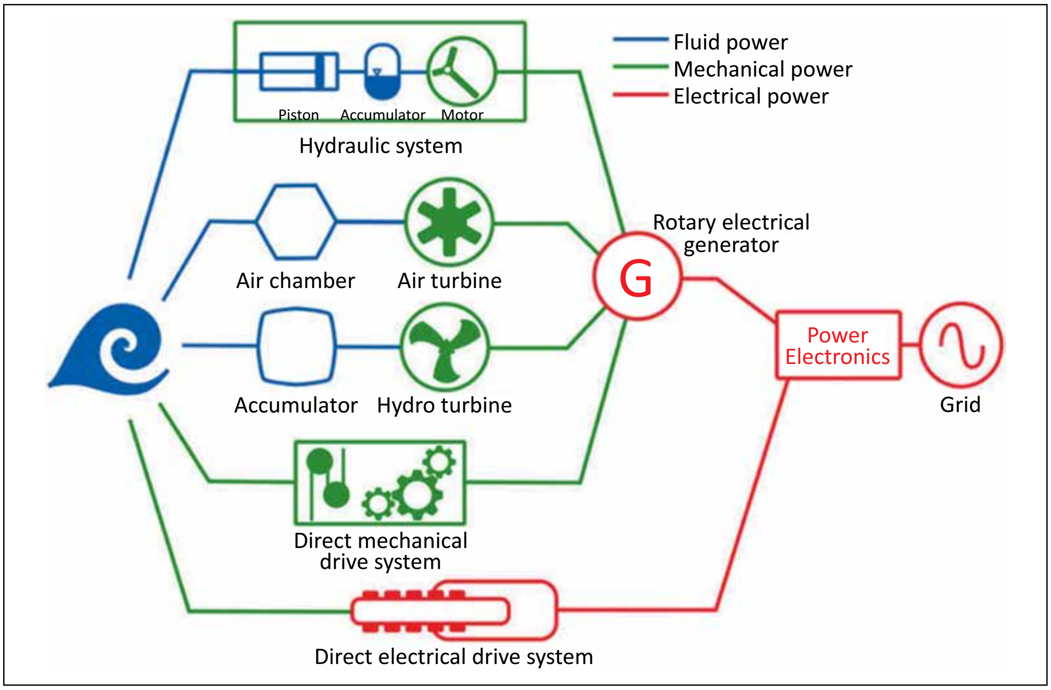
The wave power generation model presented in this research uses a direct conversion system where its force transmission elements are composed of pulleys and gears, aiming to reduce losses from composite processes, thus optimizing the transmission of resulting forces from the oscillation of the waves to the electric generator. Figure 2 below illustrates the modeling of the power take-off system in 3D using CAD software with real dimensions of the patent.

Modeling in Ansys Aqwa Environment

From the initial wave power generation (GEO) model conceived by Hidrobombas, with the dimensioning of the project structures and modeling in a three-dimensional environment of the prototype carried out by LACTEC, it was possible to carry out the analysis of the centers of gravity and moments of inertia of the structure. Figure 3 shows the centers of gravity obtained via Autodesk Inventor® software calculations and Table 1 shows the mass properties and moments of inertia of the structures, concerning the respective centers of gravity.

From the simulations carried out in an Ansys Aqwa environment of the simplified system with fewer components and surfaces, it was possible

Figure 1. PTO models.

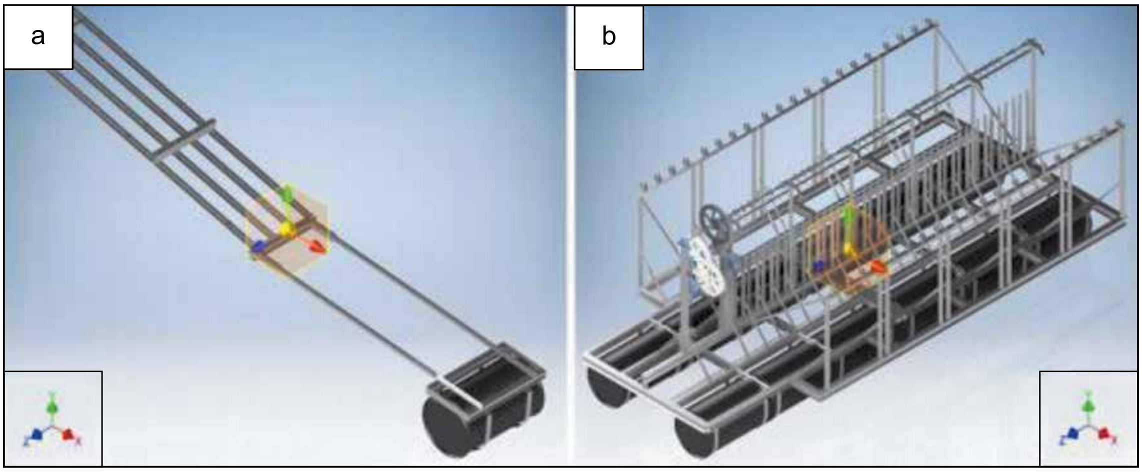


Source: (Amélie Têtu, 2017).

Figure 2. 3D CAD modeling.

Source: Technical Report 2.2 - GEO Project.

Figure 3. Centers of gravity for the structure of the GEO arm (a) and central body (b).



Source: Technical Report 2.2 - GEO Project.

Table 1. Inertial properties of GEO components.

Structure	Mass (kg)	lxx (kg.m^2)	lyy (kg.m^2)	lzz (kg.m^2)
Main Body	1293	4390	4633	1356
Articulated Arm	135	30	446	456

Source: Technical Report 2.2 - GEO Project.

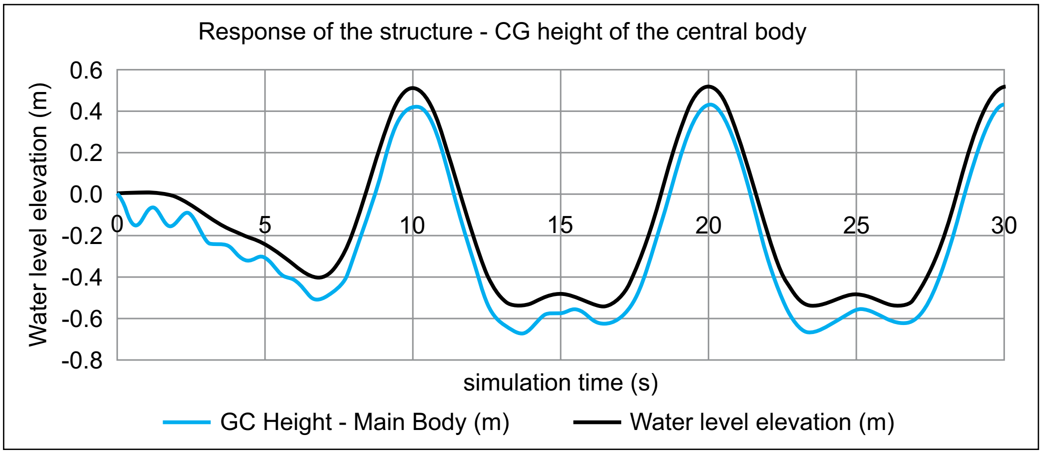
to evaluate the fluid-structure interactions. Thus, the analysis of the behavior of patent BR 10 2016 016119 3 A2 in a near-shore and offshore environment can be studied in compliance with the physical characteristics of the real model. For technical evaluation of the behavior of the structure proposed by the research patent, simulations were carried out in different scenarios of wave directions, enabling the understanding of the dynamics of the system when anchored to a physical structure compared to the free-floating system.

To determine the classical behavior of wave energy and obtain reliable data through simulations, it is necessary to understand the study of mathematical models that address depth variation, as well as the main quantities arising from the energy conversion process (Joaquim & Calejo, 2012). As an example of the results obtained through the simulations carried out, Figure 4 shows the behavior of the structure of the main body when submitted to a regular wave, with 2nd Order Stokes theory (T = 10s, H = 1 meter). To allow the evaluation of only the vertical displacement, the displacement of the structure in the direction of incidence of the waves was prevented.

It is possible to notice that the center of gravity moves along with the wave, and therefore there is little relative movement, which impairs the capture of energy available in the waves. Figure 5 illustrates the general behavior of the floating structures of the ordomotive energy generation system, such as the rotation of the arms around the axis of rotation in which it is fixed.

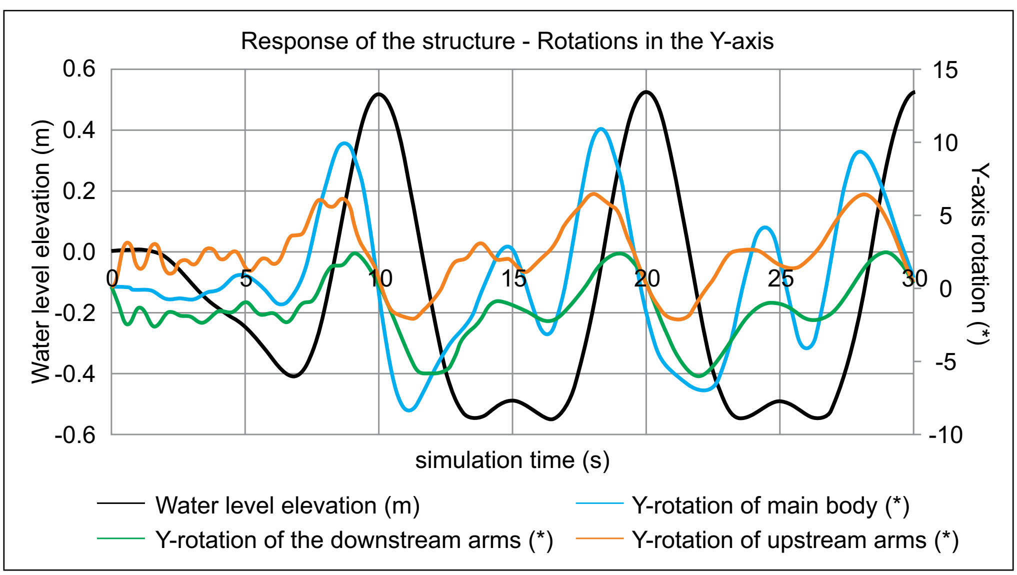
Note that because the structure rotates when following the incident wave, the arms also rotate, which results in low rotation of the downstream arms, and thus, the kinetic energy transferred to the PTO is considerably low.

Figure 4. Idealized Model Response: Z position of the CG of the central body and elevation of the water level in the YZ plane, which contains the CG of the central structure.



Source: Technical Report 2.2 - GEO Project .

Figure 5. Idealized Model Response: rotation of the components around the Y axis and elevation of the water level in the YZ plane, which contains the CG of the central structure.



Source: Technical Report 2.2 - GEO Project.

Strong Points

The identified strengths for GEO Hidrobombas are:

I. Direct generator drive, with mechanical power transmission. The absence of intermediate energy conversion systems makes the system simpler and increases the theoretical efficiency of the energy conversion system.

II. The relationship between the weight of the central body and the thrust resulting from the partial submersion of the floats is such that it gives the structure buoyancy.

III. Hidrobombas' GEO prototype does not generate residues in its operation, thus presenting a low risk of environmental contamination.

IV. As it is floating, the GEO has the advantage of being transportable and not depending on near-shore structures for rigid fixation of the generator set. In addition, its installation can occupy uninhabitable regions without economic exploitation, making it possible to obtain better use of the physical coastal space.

V. The vast majority of components used in the construction of the prototype are all commercial and easily purchased on the market. The welded structural elements are based on standardized structural steel profiles and the floats are cylinders in commercial dimensions.

Weak Points

I. The take-off (PTO) and power transmission mechanisms feature sets of pulleys, pinions with ratchets, and non-lubricated bearings that can present high friction, adding torque against the main shaft. This can lead to excessive wear of mechanical joints and reduced efficiency.

II. Some components related to system functionality are unsuitable for the marine environment and continuous operation, such as the use of elastic cords and mechanical elements exposed to the corrosiveness of the environment.

III. Human locomotion on the GEO is difficult, which can make its installation, operation, and maintenance difficult.

IV. The GEO does not have inertial reference and/or fixation points (hardpoints) for support and anchoring. Thus, relative movements between the GEO central body and the arms would imply a reduction in the arms' range of motion and, consequently, in the gravitational potential energy available in the arm when at the crest of each wave. Therefore, in addition to the GEO drift, possible efficiency losses are expected due to the absence of inertial references.

V. The absence of inertia flywheels or other kinetic energy accumulation systems of the spindle assembly, or the impossibility of insertion of electronic control systems, due to the GEO direct transmission characteristic, can result in large rotation oscillations of the generator, as well as large accelerations at the beginning of the transfer of power from the articulated arms to the main shaft and large decelerations at the end. Thus, the proper dimensioning of an inertia flywheel would provide the opportunity for a more controlled operation under a permanent wave incidence regime.

VI. Severe difficulty in adjusting the resonant frequency of the mechanical system against the frequency of incidence of waves, due to the direct characteristic of energy transmission.

Improvement Points

I. The articulated arms fixation bearings, which currently consist of screws that traverse through holes in the central structure and arm support, can be replaced by rolling bearings or low friction polymeric materials - considering the difficulty of maintaining lubrication in an environment marine.

II. Elastic cords that maintain the contact tension of roller chains with sprockets can be replaced by mechanical elements designed for fatigue life and weather resistance, such as stainless steel helical springs.

III. Enclosure of lubricated machine elements and subject to seawater corrosiveness, such as the roller and pinion chain assembly, or the main shaft and bearings.

IV. The ondomotive energy source has great temporal and spatial variability. For this reason, the prototype will tend to provide intermittent electrical power generation. To correct this, the Generator must be able to operate an output signal stability. A possible solution to this problem could be the implementation of an electrical control system that stabilizes the output signal to the network. In addition, it is interesting to insert individual sensors for each Generator Arm, among other automation components, for monitoring purposes.

V. It is suggested to optimize the load distribution in the Arm so that an optimal point is reached about the moment performed that will transmit power to the axis (displace the Center of Gravity of the Arm so that it is as far as possible from the axis central) and there is possibly an optimal distance that will depend on inertial factors and wave incidence frequency.

VI. The GEO prototype absorbs ondomotive energy through the gravitational potential energy of the arms, which, when passing wave crests, are positioned above sea level. When in the valley of the wave, the arm returns to its lowest energy position, with the movement being resisted by the power take-off system (PTO), through the set of roller chains and ratchet pinions. Thus, the increase in the system's generating capacity depends on the amplitude of the waves and the total mass in balance. Since the first is a characteristic of the ondomotive potential of the installation site and the second implies an increase in the total dimensions of the system, as well as structural reinforcement for compatibility with self-weight loads, it is proposed to design a system capable of absorbing wave energy in the arm's ascent movement (thrust) and arm's return (gravity).

VII. To provide the GEO with an inertial reference, which limits the displacements of its central structure, and considering that it is a near-shore or offshore installation system, it is proposed that the system be adapted to receive anchoring or support cables.

VIII. Another possibility that will be taken into consideration will be the replacement of the direct transmission system using roller chains and ratchets, with the use of hydraulic systems, keeping the other conceptual geometries of GEO Hidrobombas.

Conclusion

After performing the 3D modeling of the type of wave power generation patent BR 10 2016 016119 3 A2 and simulations in the Ansys Aqwa environment that allowed evaluating the behavior of physical quantities, such as component mass, gravity centers, and moments of inertia, it was possible to verify the technical unfeasibility of the project due to the performance presented from the hydrodynamic simulations, in which both the arms and the central body move along the wave, and also due to its constructive characteristics. However, there are positive points that, linked to the improvements proposed by Lactec's research staff, can enable the construction of the suggested prototype.

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