The GESMEY Ocean Current Turbine. A proposal for marine current energy extraction on deeper waters

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Abstract

The paper shows the results of the research project that has as title "GESMEY" and it has been developed in collaboration between a research team from the E.T.S. Ingenieros Navales of The Technical University of Madrid (UPM) and other from The Foundation Technological Centre SOERMAR.

The main objective of the Project it's the design and development of a new type of submarine electrical generator to get the exploitation of the marine currents energy with a good performance, that has as name "Submarine Electrical Generator with Y shape framework (GESMEY).

The GESMEY generator can work into deeper waters and it gets the right depth by itself only using a hydrodynamics force that allows it to go to the surface or dive without any other help.

This Paper has the follow structure, it begins with a brief introduction about the present situation of this technological field and also an analysis over the energetic power of the marine currents on Gibraltar's Strait it is done, as an ideal place to use GESMEY.

On following points, the Paper describe topics as the organization and methodology that was used during the development of the Project, the description of some device models and the generator's internal system with the ballast system included and the way that the generator is submerged to the work place, emerge for maintained and towered to seashore.

Keywords: Marine Current Turbines, underwater device, Power Take Off.

1. Introduction

The marine currents have origin in seas and oceans by several superposing effects that are, the tides, different density between waters, the winds and the Coriolis forces.

Mainly, the marine currents that are situated into European sole rights exploitation waters are originated by tides and on those that the mean velocity of the stream would be high is possible to get enough kinetic energy and they are an important renewable energy source.

The quantification of the energy that will be extracted from tidal and oceanic currents is over 800 TWh/year (about 4% of world electrical consume) but at present time it is not possible to exploit a significant part of this immense energetic potential. Most of this energy is concentrated in locations with depths over 40 meters and it needs a new generation of converters that will be capable to extract it.

Nowadays the Tidal Stream Developments Technology is yet in the beginning of its life and there are only developments used mainly as a test to learn more and improve the technology than to generate and sell electricity. At present time there are over sixty devices into the Tidal Stream Generation Technology and the majority of concepts utilise a horizontal axis rotational method of generation without any sign that now the industry are going to converge towards a single configurations and there are only one machine, the Marine Current Turbine's Sea Gen with 1,2 Mw generation power, that is located into the sea at the Strangford Narrows and is connected to the electrical network.

The others technological concepts are in different stages of development but not on industrial exploitation and any of them, marine Currents Sea Gen included, are not capable to exploit the currents that are at more of 40 meters depth. On the other hand the generator GESMEY it has done it and it is a second generation device to harness the energy of this deeper currents.

2. The main objective of GESMEY, the exploitation of marine currents energy on Gibraltar's Strait

Gibraltar's Strait is the natural way to join Mediterranean Sea and Atlantic Ocean and it's limited by a section between the Cape of Trafalgar (Europe) and the Cape of Esparter (Africa) at west and by the section between Punta Europe and Punta Cires (Africa) at east. It has a variable width, with one maximum of 44 km at the west entrance and one minimum of 14 km in the strait narrows between Tarifa and Punta Cires.

The strait's axis goes in east-west direction along 60 km over 36º N parallel and the bathymetric profile is irregular, with average depth of 550 m in the main channel and zones where are 90 m only and another with ones with maximum depth of 960 m.

The energetic resource that the strait perform is making up by a double current that it is originated by several superposing effects that are, different density between both masses of water, the different level between the ocean and the sea, the tides that are generating in the Atlantic side of the Strait and go into the Mediterranean Sea and the currents originated by local winds.

The principal part of the energy associated to the tides is into the upper atlantics waters currents and it is going along an hypothetic channel surrounding by the sea surface and one level that is situated over 100 meters depth.

Another big part of the energy is associated to the low waters current that is going along the channel worked in the sea bed by the waters.

On the Strait there are several places with a maximum current's speed up 2 m/s but normally they are in deep waters, more of 50 meters depth, usually on 80 or 100 meters.

So, was the challenge to exploit the energy of these currents the task that a new type of device would have and this new device GESMEY is.

The project main objective is to develop a low life cycle cost device, designed for Gibraltar's Strait and others world sites with waters depth over 40 m and the goals that this new design will have, are:

- Simplified deployment
- Minimum environmental impact
- Without surface elements on operation
- Robust and simple construction
- Scalable (depth, stream, speed, nominal power)
- Use of mature COTS technologies

And with those requests a new conceptual design, the "Submarine Electrical generator with Y shape Framework" (GESMEY), was done.

GESMEY generator will have one rotor with several blades that it propels one electrical generator, placed into a pod and joined to it there are tree columns situated on a perpendicular plane with the axis of the rotor and at the end of each column there is one float with torpedo shape that has its axis in a parallel way to the rotor's one.

3. Project organization and work methodology

The Goal of the Project it is the design and development of a new type of submarine electrical generator (GESMEY) to get the exploitation of the marine currents energy with a good performance.

The GESMEY generator will can work into deeper waters and it gets the right depth by itself only using hydrodynamics forces that allows it go to the surface or dive without any other help.

The basis of the Project was an idea from the Professor Lopez Piñeiro patented by the Technical University of Madrid (UPM) and all the Project has been developed in collaboration between a research team from the E.T.S. Ingenieros Navales of The Technical University of Madrid (ETSIN) and other one from the foundation Technological Centre SOERMAR.

The Project has been supported by funds from The National Research Program 2008/2011(Subprogram of Industrial Applied Research, Call 2008), ministry of the Industry, Tourism and Commerce of the Spanish Administration.

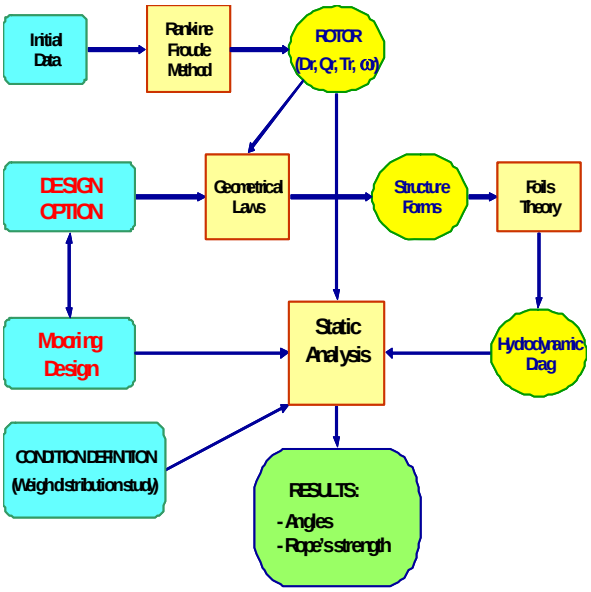

Figure 1: Flux Diagram of the Methodology used

And over the basic concept of GESMEY generator, there were a lot of design options and it was necessary to do a feasibility study to choose one of them as initial design to make the functional design of the device.

To carry out this task it was used one methodology that it is based on the following five points:

1. Conceptual design, previous assessment and drawing of the option.
2. Basic calculation on the global performance of the option.
3. Analysis over the fortress and weakness of the option.
4. Choice of the best option.
5. Numerical simulation of the performance of the chosen option.

The flux diagram that shows this methodology is in Fig. 1

In the first step the feasibility study was done for a generic generation with the following initial data:

- Power take off 1Mw
- Main velocity of the stream 3 m/s
- Velocity of the end of the blade 15 m/s
- Depth of the sea bed 60 m
- Depth of the work place 30 m

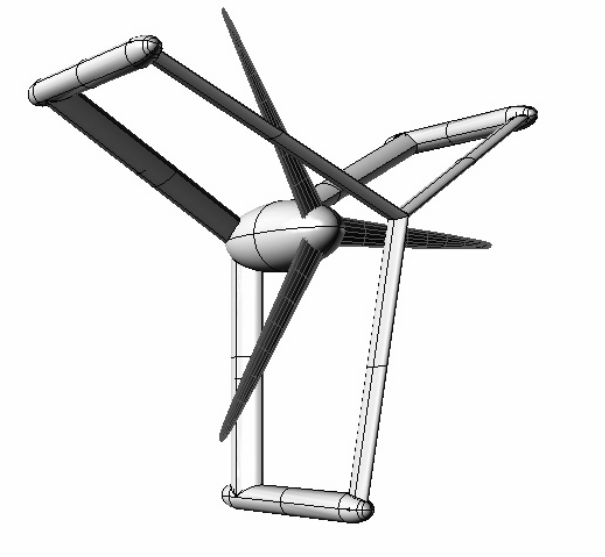

Figure 2: General View of GESMEY A6.7

4. Description of the chosen options

At the end of the process two options were chosen, one of them is a generator GESMEY A6.7 with 600 kW of power and it's optimum for places with bidirectional current's flux and the other GESMEY U1M with 1 Mw of power for places where the one way flux of the stream is highest. Both of them are shown on Fig. 2 and Fig. 3.

Description	GESMEY A6.7	GESMEY U1
Power (kW)	600	1000
Stream Highest velocity (m/s)	2,0	1,8
Sea bed depth (m)	60/100	80
Rotor diameter (m)	20	32
Minimum end of the blade depth (m)	15	34
Rotor (RPM)/Gear output (RPM)	12/1500	12/750
Structure	steel	Steel
Number de devices in a generation's park	20/50	20/50

Table 1: General Specifications

The main parts of the two concepts of GESMEY design are:

- Rotor:
  - o Fixed pitch blades to improve efficiency and reliability
- Central Pod (Based on COTS elements):
  - o Power take off components
  - o Auxiliary systems
- Columns:
  - o Main structural parts
  - o Auxiliary ballast parts
- End Torpedoes:
  - o Main ballast tanks
  - o Stability on operations with asymmetric loads
  - o Stability on flotation like a semisubmersible platform

And the General Specification of the two devices is shown on Table 1.

Figure 3: General view of GESMEY U1M

5. Description of the internal systems

Into the pod there are located the main elements of the electro mechanical train and also several auxiliary elements, all of them are related on the following list:

a) Rotor with tree blades
b) Low velocity axis
c) Water seals
d) Row lock
e) Low velocity brake disc
f) Two low velocity brakes
g) Planetary gear
h) High velocity axis and brake disc
i) Three high velocity brakes
j) The gear to turn back
k) The alternator with permanent magnets
l) Bilge pump
m) Planetary gear refrigeration system
n) Refrigeration system of the alternator
o) Safety switch
p) Electrical panel of 230 V
q) Electronic control panel
r) Compressed air bottles
s) Ballast system manifold

The display of those elements into the pod is shows in the Fig. 4 and it is cover with an ellipsoidal envelop that allow a good hydrodynamic performance.

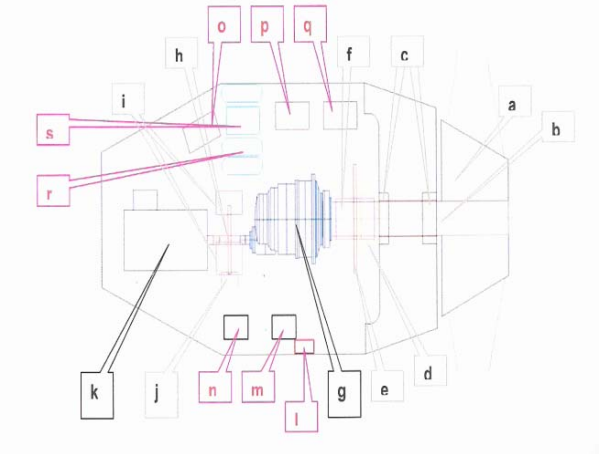

Figure 4: Main and auxiliary elements into the Pod

6. The ballast system and the ways of operation

The ballast system allows changes in the position of the device, from surface to the operation place (submerged) and also the device emersion and floating on the sea surface for first level maintenance or its transport to the sea shore.

The main elements of this system are, ballast tanks situated into torpedoes and columns, compressed air bottles, charge air equipment, valves and the electronic control system.

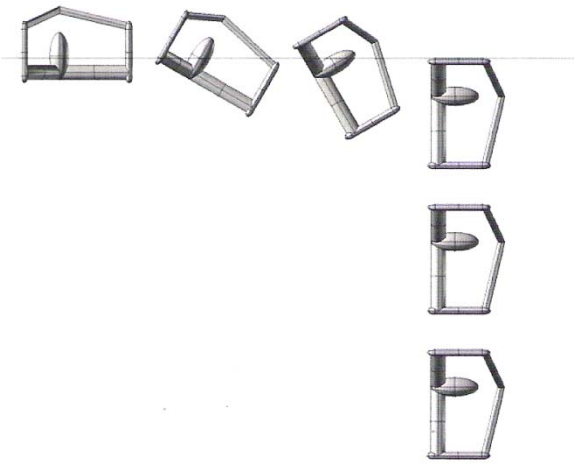

Figure 5: Immersion procedure

The GESMEY generator is transported on float by a tug vessel and when it reaches the location where the vertical of the place of operation is, the immersion procedure is begins and the device is placed on the right position by a specific mooring system and controlling the ballast level as it is showing on Fig 5 and Fig 6.

When the emersion of the device will be necessary for maintenance on flotation, the rope of the mooring system is detached and the ballast level changes because ballast water is expelled out by the compressed air and the device go up to surface, there change another time the main axis position from horizontal to vertical direction and lays floating over the waters, ready for maintenance operations or if it needs the device will be transported on float to a port or a shipyard. The final state of the emersion operation is shows on Fig. 7.

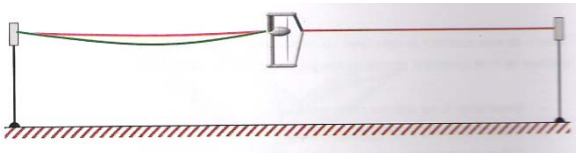

Figure 6: GESMEY work position

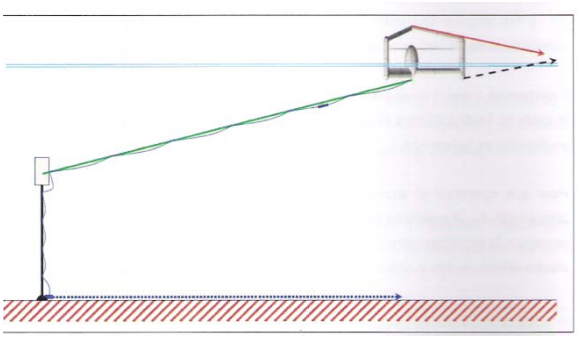

Figure 7: GESMEY final emersion position

7. Conclusions

- GESMEY is a new concept of electrical generator that will be able to exploit marine currents energy on sites with rotor depth over 40 meters.
- GESMEY has a minimum environment impact because it works submerged but don't lie over sea bottom and when its life cycle is finished, it will be removed without any problems to the marine environment.
- GESMEY has a robust and simple construction.
- GESMEY has the possibility to exploit currents with steam speed below 2 m/s.
- GESMEY not need special vessel or offshore artefacts to transport and positioned in the operation site, also to emerge and remove.
- GESMEY will have a low cycle cost because the installation, maintenance operations and the final remove, will be more cheap than other devices that at present time are.
- GESMEY needs a very simply mooring system that has a minimum environment impact over the marine ecosystems.

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