Ocean Waves Hydro-Electric Power Station using a Gravitational Electrical Generator on Magnetic Fluid Cushion

NICOLAE CALIN POPA[1], ALI SIBLINI[2], JEAN JACQUES ROUSSEAU[2],
NICOLAE CRAINIC[3]

[1]Centre for Advanced and Fundamental Technical Research (CAFTR)
Romanian Academy – Timisoara Branch
Bd. Mihai Viteazul nr. 24, 300223 Timisoara
ROMANIA
ncpopa@flumag2.mec.upt.ro or ncpopa@acad-tim.tm.edu.ro http://acad-tim.tm.edu.ro

[2]Université de Lyon, F-42023, Saint Etienne, France; Université de Saint Etienne,
Jean Monnet, F-42023, Saint Etienne, France; LT2C, F-42023, Saint Etienne, France
FRANCE
jean.jacques.rousseau@univ-st-etienne.fr, ali.siblini@univ-st-etienne.fr
http://portail.univ-st-etienne.fr

[3]Research Centre for Complex Fluid Systems Engineering
"Politehnica" University of Timisoara
Bd. Mihai Viteazul nr. 1, 300222 Timisoara
ROMANIA
ncrainic@flumag2.mec.upt.ro or ncrainic@gmail.com http://www.upt.ro

Abstract: - After a short introduction in the general problem of capturing the energy of the ocean waves the paper describes the hydro-electric power station based on the gravitational electrical generator on magnetic fluid cushion. This is constructed from a permanent magnet in a magnetic fluid shell, which, under the action of the ocean waves, is moving by translation inside a hermetically sealed tube. The transformation of the kinetic energy of this permanent magnet in electrical energy is possible using some electrical coils placed in the exterior of the tube and connected in an electrical circuit described in the paper. We present a possible way of placing the gravitational generator on the waves and a comparison of this energetic system with similar ones.

Key-Words: - Magnetic fluid, Ocean waves energy, Hydro-electric power station, Electrical generator, Clean energy, Renewable energy, Alternative power sources.

1 Introduction

Since more than 200 years the humanity has considered the importance of the sea and ocean waves energy and has tried to capture this energy and to express mathematically the profile of the waves. The first recorded patent was granted in 1799 to a Frenchman, M. Girard ([1]) and the first important mathematical model was realized by a Czech, Gerstner, in 1804. A special activity in this research field was developed in the eighties of the twentieth century when the price of oil increased ([2]).

In fact, the energy of the ocean waves is a form of wind energy. Although at this moment the research is more moderated, it goes on ([3] – [12]) because one of the most promising renewable sources of electric power is the ocean swell.

Typically 2 - 3 m high, these waves have a period of 10s and on the average they contain a power between 40 to 90 kW for every meter of wave front. Until now, a great number of capturing devices for wave energy was developed, but, no one was categorically preferred. However it has been possible to obtain some conclusions about how to capture and transport the waves energy and it seems that it would be better to obtain at the end an electrical energy (instead of thermal or hydraulic energies).

The electrical energy is the easiest to be transported at a long distance or to be locally used for salt removal, hydrogen fabrication a. s. o.

Generally, these hydro-constructions have big physical dimensions (especially unmovable constructions), so, for technical and economical reasons many small energy unities are preferred instead of a big one. The preference for electrical power as final power leads to use designs which convert directly the wave power in electrical power. From an electrical point of view the easiest conversion is in direct current ([2]).

2 Gravitational electrical generator on magnetic fluid cushion

The expression of the momentary electrical voltage u_e, induced in an electrical coil with N_s loops, by a magnetic field varying versus time, is very well known.

$$u_e(t) = -\frac{d}{dt}\left[\sum_{i=1}^{N_s} \Phi_i(t)\right] =$$
$$= -\frac{d}{dt}\left[\sum_{i=1}^{N_s} \int_{S_i} \vec{B_i}(t) \cdot d\vec{s}\right] \quad , \qquad (1)$$

where S_i = surface of the loop i; $\vec{B_i}(t)$ = magnetic induction vector through the loop i at the moment t, and, $\Phi_i(t)$ = the flux of the magnetic induction vector through the loop i, at the moment t.

The magneto-fluidic levitation of the second order makes to auto levitate a permanent magnet on which there was poured enough magnetic liquid. In this case, the permanent magnet puts between it and the bottom of the vessel, a magnetic liquid layer, which transforms the dry friction between the magnet and the vessel, into a wet friction (viscous) which has a very small value.

The magnetic induction vector $\vec{B_i}(t)$ from the equation (1) is created by the auto levitated permanent magnet and the time variation of the magnetic induction, which is necessary to obtain the induced electrical voltage, results by moving the permanent magnet in front of one (or several) fixed coils ([4]).

The movement of the permanent magnet (surrounded by the magnetic liquid) in the neighbourhood of the electrical coils, can be produced by the vertical (and horizontal) movement of the ocean waves. In this purpose, the permanent magnet surrounded by the magnetic liquid, is placed in a hermetically sealed tube. To produce the translation movement (sliding) of the magnet, the tube floats on the waves and inclines because of them, on a longitudinal direction, in one sense and the other.

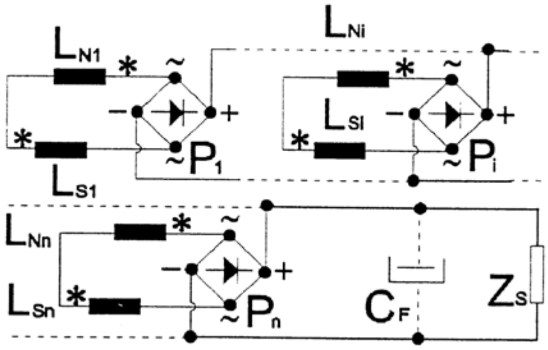

Fig. 1: Simplified electrical schema for the energetic line. L_{Ni} = Electrical coils placed in the neighbourhood of the North Pole of the permanent magnet; L_{Si} = Electrical coils placed in the neighbourhood of the South pole of the permanent magnet; P_i = Rectifier electrical bridges; C_F = Impulses filtering system by energy accumulation; * = Beginning of the winding; Z_s = Load impedance.

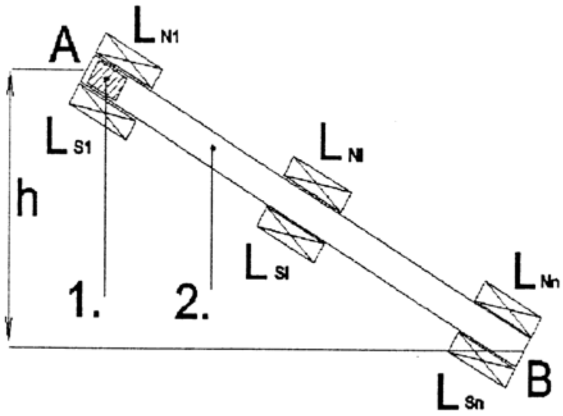

Fig. 2: Energetic functioning principle for the gravitational generator on magnetic liquid cushion. L_{Ni} = Electrical coils placed in the neighbourhood of the North Pole of the permanent magnet; L_{Si} = Electrical coils placed in the neighbourhood of the South pole of the permanent magnet; 1. = Permanent magnet in its magnetic liquid shell; 2. = Hermetically sealed tube.

To convert the waves energy into electrical energy, we place pairs of electrical coils (at least 2 pairs, when they are placed one pair at each end of the tube), along the tube, thus during its translation movement, the permanent magnet is shifted with the North and South poles in front of each pair of coils (Fig. 2). When the magnet reaches one pair of coils, an electrical impulse is obtained. This impulse (and all the other ones) can be rectified, and its electrical energy can be transferred to an energetic line of direct current. The simplified electrical schema of such a device is presented on Fig. 1.

From energetic point of view, the problem is presented on Fig. 2. Let's consider *m* the mass of the permanent magnet which is surrounded by the magnetic liquid and placed in the hermetically sealed tube. The tube is inclined so that the A end is at the *h* height from the B end. To simplify, we assume that the tube remains in this position for all the duration of the magnet movement. When the magnet is in point A, it has a potential energy E_p in comparison with point B, given by the expression $E_p=mgh$ where g is the gravitational acceleration.

We assume that from some reasons, the magnet slides to point B without delivering electrical energy in the L coils. As the friction with the tube walls is very small because of the presence of the magnetic liquid, the magnet has a uniformly accelerated movement, and arrives in point B with the v'_B speed. We can say that

$$mgh = \frac{mv'^2_B}{2} . \qquad (2)$$

If during the movement, the magnet gives up energy to the coils, it will be braked in front of each coil because of the electromagnetic effect, and it will arrive in point B with the speed $v_B < v'_B$. The energy given up to the electrical circuit is expressed by the equation:

$$\Delta E = \frac{mv'^2_B}{2} - \frac{mv^2_B}{2} = mgh - \frac{mv^2_B}{2} \qquad (3)$$

Placing one pair of coils at each end of the tube, with a proper design of these coils, v_B can be brought almost to zero, whichever the sense of the movement of the magnet is. The energy given up to the electrical system at one time when the magnet goes through the tube is given by the expression

$$\Delta E = mgh \qquad (4)$$

The positioning on the waves, of the gravitational generators on magnetic liquid cushion from Fig 2, can be done for instance with the help of some continuous and articulated rafts, like the ones in Fig. 3. Inside these hermetically sealed rafts, we put a large number of gravitational generators which are electrically connected, like in Fig. 1. Each one of these systems can be an independent energetic system, which has the possibility of accumulation, transformation or transmission at distance, of the electrical energy.

A substantial increase of the quantity of energy got from waves by the gravitational electrical generator on magnetic fluid cushion can be obtained by holding the permanent magnet at the ends of the tube, until the tube has a minimum inclination, which is determined considering the average geometrical and dynamical properties (the speed) of the waves in that moment. Considering these parameters we can also determine the optimum length of the tube and the optimum number of the energy capture pair coils.

The holding of the permanent magnet at the ends of the tube can be obtained by placing at the ends of the tube, small ferromagnetic bodies (with proper geometry), at a certain distance from the limit of the permanent magnet moving.

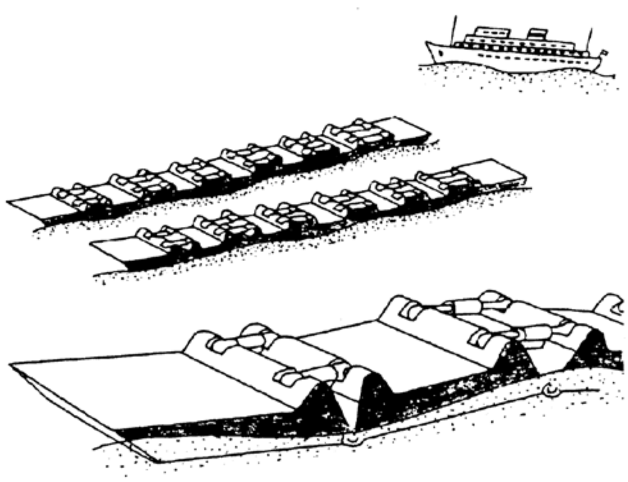

Fig. 3: Continuous and articulated rafts with hydraulic functioning developed in U.K. ([2]).

If we place small electrical coils around these ferromagnetic bodies near the ends of the tube, we can get an automatically adjustment system for the inclination angle at which the permanent magnet is able to move. The electrical supply for these head coils is an electrical impulse, at the same time (or not) for all the gravitational generators of the same section of a raft. The command moment depends on the information about the inclination of the raft section (obtained from an inclination transducer), and about the average geometrical and dynamical properties of the waves.

With these remarks, in first approximation, is justified the physical model in which the gravitational generator remains at the same inclination during the whole time of the magnet run.

There are also other modalities (without electrical power consumption) to retain the permanent magnet at the ends of the tube until the tube has a certain inclination.

3 Similar energy capture systems

From the point of view of the exterior mechanical construction of the energetic system, the rafts for the gravitational generators can be compared with the continuous rafts made in U.K. (Fig. 3) ([2]). Functionally (inside), the two systems are totally different, the raft system from Fig. 3 being equipped with hydraulic pumps between each two consecutive raft sections, and converting the wave energy into hydraulic energy.

From an electrical point of view the gravitational generator can be compared with the direct magnetic converters made in Egypt and which are usually fixed marine constructions ([2]). They produce the electrical energy with the help of the relative movement of some permanent magnets and coils under the actions of the waves. These types of direct magnetic converters need a mechanical amplification of the relative speed of the permanent magnets towards the coils, which is realized with wheels and driving belts. Unlike these, the gravitational generator uses the gravitational acceleration for the speed enlargement.

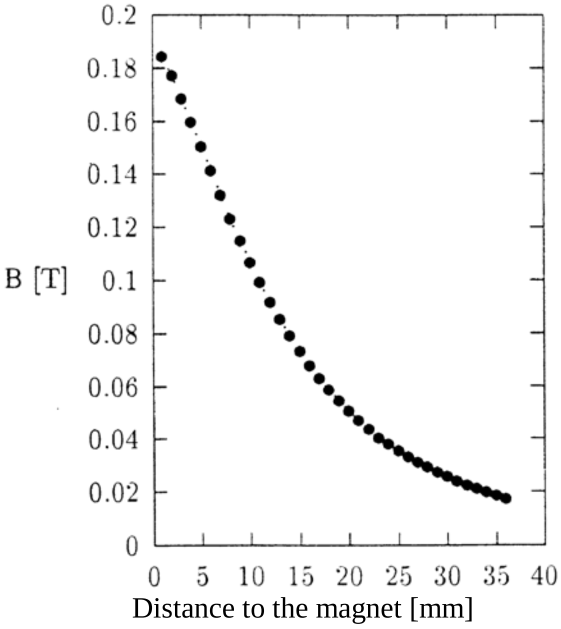

Fig. 4: Magnetic induction B (in Tesla) (for the permanent magnet used inside the generator) measured on air, on the central axis of the magnet, perpendicularly to the North Pole face, versus the distance to the magnet (in mm).

4 Experiments

We made a computer program for the dimensioning of the gravitational generator, and we theoretically analyzed the influence of each parameter to overall dimensions. We established that, for many reasons, the coils must have special magnetic cores (some details in [4]) placed in special magnetic circuits.

The permanent magnet used at the first experiments (weight 162g and dimensions 45 mm x 28 mm x 11 mm) had the magnetic induction as in Fig. 4. Without optimize the magnetic circuit, the generator transformed in electrical energy maximum 78% of the available mechanical energy.

Theoretically, using an optimal magnetic circuit, the transformation efficiency is over 90%.

5 Conclusions

These gravitational generators can be used for one direction of the waves, or for two directions of the waves (when we mechanically put together two generators, at 90 degree one to other). In this case, a future research will answer at how much of the waves energy can be theoretically transformed in electrical energy (using this principle), or, how much electrical energy can be obtained from a surface unit of the ocean.

The constructive technical solutions for the cores belonging to the energy capture coils, and, for the retaining of the permanent magnet at the ends of the tube, are very important.

One of the most important advantages of the gravitational generator is that it uses small work speed. It doesn’t need a mechanical amplification of the relative speed of the permanent magnets towards the coils, so, it doesn’t need wheels and driving belts. It uses the gravity for that. Other advantages are the small physical dimensions (relatively to other type of hydro-constructions) and the possibility to build an important part of the “electro-power station” in a factory and not on the ocean.

This type of electro-power station, using a relative large surface of the ocean, can work (under the new concept of “renewable energy sources in combined systems” ([9]-[12])) combined with the solar energy.

Acknowledgements

This work was partly supported by the Project PN II nr. 157/2012 "MagNanoMicroSeal" (2012 - 2015).

References:

[1] Brian M. Count, Exploiting Wave Power, *I.E.E.E. Spectrum*, September 1979, pp. 42 - 49.

[2] Charles Simeons M.A., *The Use of Water as an Alternative Source of Energy*, Pergamon Press, 1980.

[3] Michel Benoit, On Some Advanced Physical and Numerical Models for Studying Sea Waves and Their Effects, *Electricité de France*, EDF 1996.

[4] N. C. Popa, A. Siblini, L. Jorat, Gravitational electrical generator on magnetic fluid cushion, *J. Magn. Magn. Mater.*, 201 (1999) pp. 407 - 409.

[5] J. Arai, R. Yokoyama, K. Iba, Y. Zhou, Y. Nakanishi, Voltage Deviation of Wind Power Generation due to Wind Velocity Change, *International Journal of Energy*, Issue 2, Volume 1, 2007, pp. 33-36.

[6] Henry Cheng, Yunhe Hou, Felix Wu, Probabilistic Wind Power Generation Model: Derivation and Applications, *International Journal of Energy*, Issue 2, Volume 5, 2011, pp. 17-26.

[7] Kostas Philippopoulos, Despina Deligiorgi, Statistical Simulation of Wind Speed in Athens, Greece based on Weibull and ARMA Models, *International Journal of Energy and Environment*, Issue 4, Volume 3, 2009, pp. 151-158.

[8] Marius-Constantin Popescu, Nikos E. Mastorakis, New Aspects on the Implementation of Wind Farms in Romania and Greece, *International Journal of Energy and Environment*, Issue 1, Volume 4, 2010, pp. 18-26.

[9] Petr Mastny, Antonin Matousek, and Jan Machacek, Renewable Energy Sources in Combined Systems – On-line System for Measuring and Collecting Data, *International Journal of Energy*, Issue 3, Volume 1, 2007, pp. 59-64.

[10] V. Pozeb, D. Goricanec, T. Krope, The Future of Europe's Energy Policy: The Legislative Framework and the Soft Law Instruments, *International Journal of Energy*, Issue 4, Volume 5, 2011, pp. 88-95.

[11] Ticiano Costa Jordao, Ernesto Lopez-Valeiras Sampedro, Estefania Rodriguez Gonzalez, Robert Bata, The Strategic Planning for Renewable Energy Sources Deployment in the Czech Republic with the Support of Balanced Scorecard, *International Journal of Energy and Environment*, Issue 3, Volume 5, 2011, pp. 364-376.

[12] Bedri Dragusha, Besim Veselaj, Xhevat Berisha, Use of Solar Energy for Water Heating, *International Journal of Energy and Environment*, Issue 1, Volume 3, 2009, pp. 135-142.