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INNOVATIVE COMPLEX INSTALLATIONS FOR THE ECO-ELECTRICITY PRODUCTION IN COASTAL AREAS

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Abstract

In order to ensure a sustainable development, it was necessary to develop technologies for capturing, storing and transforming the energy produced by renewable sources into electricity. In this sense, they have been designed and put into operation a number of facilities for obtaining green energy. Even if, over time these have been optimized to increase the efficiency of electricity production, they had disadvantages in terms of environmental impact. Besides being occupied by large areas of land or represented high accident risks, conventional facilities for generating electricity from renewable energy sources had high costs of production, transport, installation and maintenance. Following the advanced research in the field of energy and environmental protection, a vertically-developed complex installation has been developed, at the laboratory level, that captures and transforms solar radiation, wind power and wave energy into electricity. This has been adapted for coastal areas and it can be the source of electricity in disadvantaged areas. Exploitation of the complex system is continuous, with high efficiency, regardless the weather conditions. At the same time, the vertical development of the complex involves the setting up of some small areas, with an insignificant impact on the aquatic environment.

Keywords*: coastal areas, eco-electricity, innovative installations, renewable energy.*

Introduction

The European Commission has promulgated a package of laws and directives (also called the 20-20-20 package) through which energy industry must focus on reducing environmental impact by adopting suitable and measurable directions. This package of laws and directives aims to reduce CO_2 emissions with 20% until 2020 compared to 1990, 20% of EU-produced energy from renewable sources, and energy efficiency to be improved with 20%.

In this context, it has been necessary to develop technologies for capturing and storing energy from wind, waves, sun, etc. to accomplish the requirements of the European Commission and also to ensure a sustainable development by substantially reducing human impact to increase the greenhouse phenomenon effect [1] and the exhaustion of natural resources.

The wave’s power represents a renewable and inexhaustible source of energy. In order to use this source, several types of installations were developed and are currently used, all of them having several common disadvantages. Through their location, the currently used devices have a strong landscape impact, can disrupt maritime traffic, can modify coastal habitats and can create noise affecting marine life in the proximity [2], [3]. At the same time, the efficiency of these systems has a discontinuous character, mainly due to wave intensity variation [1], [2].

Although it is an important source of renewable energy [1], wind power has a fluctuating character and is not adequate to satisfy the electricity demand [4]. In order to capture as much wind energy as possible, usually the installations are located in favorable areas where the air currents are of significant intensity, otherwise the location of wind farms

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in areas which are not suitable for these conditions may have a negative effect on their efficiency [5]. Wind farms cover significant areas posing a strong landscape impact (Fig. 1) [1], [4], and the wind turbines may be a threat to habitats, affecting birds in particular [4]. Taking into account the wind farms noise pollution, it is recommended to not use these installations in urban areas [4]. To these inconveniences is added the one related to the extreme meteorological phenomena which can cause damages to the wind turbines, thus harming the safety of the people nearby (Fig. 2) [5].

Fig. 1. Fântânele-Cogealac Wind Farm, Romania [6]

Fig. 2. Wind turbine fire - Locust Ridge Wind Farm, USA 2 [7]

Even if it can be considered as one of the renewable energy sources with the greatest potential, the solar energy presents a number of disadvantages [8]. Firstly, solar energy is an intermittent source of energy due to day-night alternations, and its efficient use requires the development of an adequate storage system [1]. According to the data from the literature, solar panels have an average efficiency of converting radiation into electricity (max. 22%) (Fig. 3). This means that, in order to contribute to the provision of electricity, are required impressive land surfaces [9], [10]. In most cases, agriculture areas are used, which are thus out of use.

Fig. 3. The photovoltaic park of Livada, Satu Mare, Romania (56 MWh) [11]

In addition to these disadvantages, the conventional installations for the production of electricity from renewable energy sources have high costs of production, transport, installation and maintenance.

In this context, the present paper addresses the issue of the development and adoption of innovative solutions aiming to capture and to transform the renewable energy into electricity and at the same time to fulfil the necessary characteristics to decrease the mentioned inconveniences.

Design of Experiment Setup

Concrete Reinforcement Design

Starting from the effect of direction and concentrating a fluid in a cylindrical enclosure, the INCDPM team of researchers have developed, a laboratory-scale integrated system with applicability in coastal areas, that uses, in the same electric system, 3 natural energy resources to produce eco-electricity [1], [12].

Initially, a theoretical research on the effect of the deflectors - slots system was performed. Deflectors are devices which, under the action of air currents, create overpressures and depressions whose final result activates air circulation [13]. At the same time, the slots are defined as rectangular sectional air jets at which the ratio between the two sides: the width of the slot (b) and its length (L) is less than 0.1 “(1)” [14].

$$\frac{b}{L} < \frac{1}{10} \tag{1}$$

The movement of the air discharged through the slot has the properties of a planar jet, characterized through the fact that, in any perpendicular plane to the surface of the slot, the characteristics of the air movement are identical. Planar jet is free, if its transverse or longitudinal development is not impeded by the presence of some surfaces. Instead, if the planar jet develops so that a parallel surface to its axis limits its transversal development due to the Coandă effect, the jet sticks to the surface [14]. In principle, the Coandă effect consists of creating a depressed area in full air along a wall, which allows the fluids to project and take the direction of the wall where the depression was generated (Fig. 4 and 5) [15].

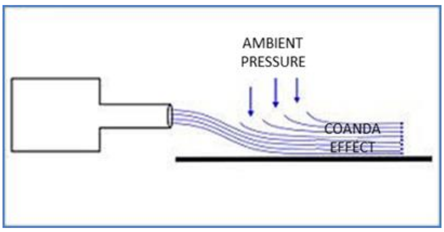


Fig. 4. The effect of deviation of a jet on a flat surface [16]

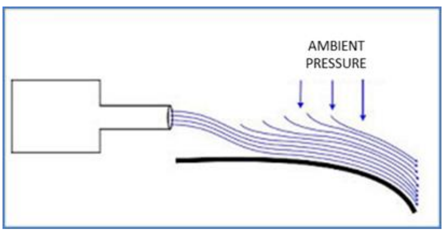


Fig. 5. Jet around a convex surface [16]

In the literature there are mentioned several calculus relations deduced from the laws of jet glued to an area. Thus, in order to determine the variation of the maximum velocity vx of the jet cross section at the distance X from the discharge section, the calculation formula “(2)” can be applied [14]:

$$\frac{v_X}{v_0} = K\sqrt{\frac{2\mu b}{X}} \quad (2)$$

Where the effective discharge velocity v_0 is determined by the air flow through the slot q (m^3/s), the width and length dimensions of the slot, the flow coefficient μ and the discharge port constant K (K = 2.4 - 2.6) "(3)"[14].

$$v_0 = \frac{q}{\mu b L} \quad (3)$$

Based on these theories, a laboratory model (Fig. 6) was developed, with a deflector - slots system. The model is made up of two cylindrical modules with different diameters, one aerial and one submersible.

The aerial module captures wind and solar energy. It is equipped with a vertical axis with coupling for rotational movement multiplication, located on a technological area. On the central axis there are 8 rows of trapezoidal blades arranged one in the extension of the other, in perpendicular planes (total 32 blades). On the aerial cylinder generators there are provided 16 vertical slots whose width can be adjusted by a system of 16 deflectors, arranged on the length of the slots according to (Fig. 7). The deflector - slots system serves to direct and concentrate the air flow towards inside the module, and thereby exert additional pressure on the blades disposed on the vertical axis. At the same time, in order to capture the solar energy, the deflectors are provided with photovoltaic cells.

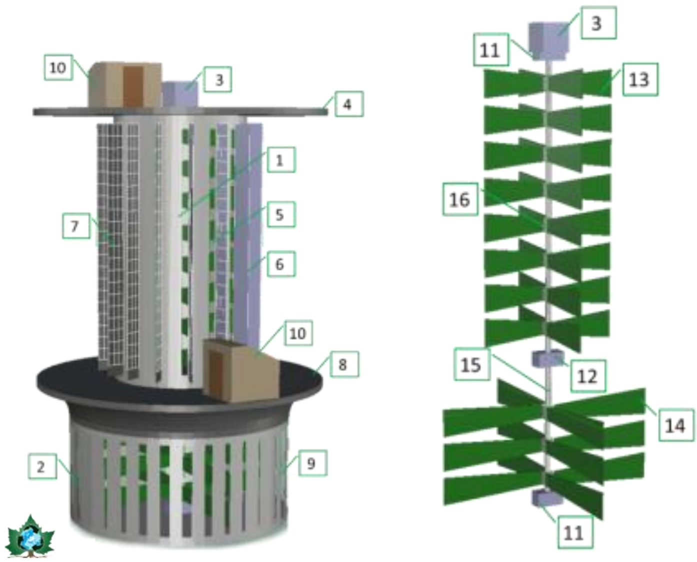


Fig. 6. Off-shore complex for renewable energy production: (1) Aerial module; (2) Submerged module; (3) Coupling for rotational movement multiplication; (4) Technological area 1; (5) Slot type 1; (6) Deflectors; (7) Photovoltaic cells; (8) Technological area 2; (9) Slot type 2; (10) Control cabin; (11) Box with axial bearings; (12) Box with pressure bearings; (13) Propeller blades type 1; (14) Propeller blades type 2; (15) Central axis; (16) Clamping system: propeller blades – central axis

The submersible module, with cylindrical shape, captures the wave energy. It is connected by the aerial module, the resulted space as the difference between the two diameters being used as a technological space, having circumferential beams. On the central axis of the module there are 12 blades of trapezoidal shape. Also, to increase the effect of hydraulic pressure on the blades, the cylinder generator is provided with vertical slots inclined towards the inner walls of the cylinder.

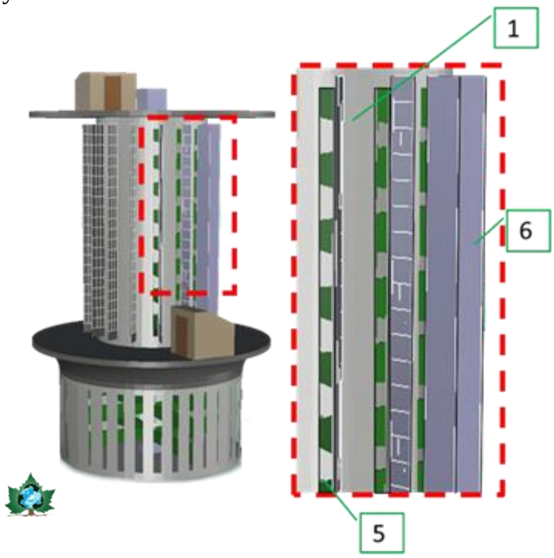


Fig. 7. Off-shore complex for renewable energy production. Detail deflector-slots

The laboratory model fixing device is similar to marine platforms and consists of lattice beams (Fig. 8).

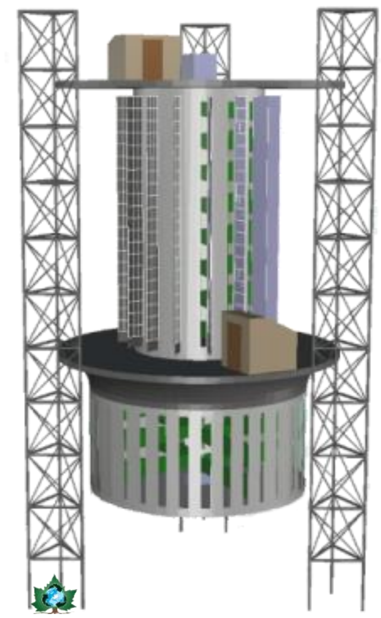
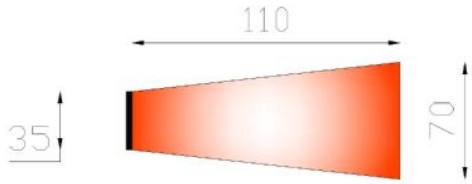


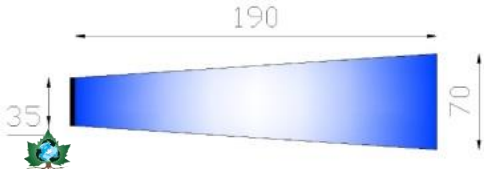
Fig. 8. The fixing device of the off-shore installation for the renewable energy production

The laboratory model consists a central axis coupling-decoupling system, which allows the two modules to operate simultaneously or independently.

Initially, at the design stage, the complex system was conceived to have the dimensions comparable to a petroleum platform. The laboratory model was developed at a lower scale, the sizes of the main components being represented in (Fig. 9).



Blades dimensions - aerial module



Paddle dimensions – partially submerged module

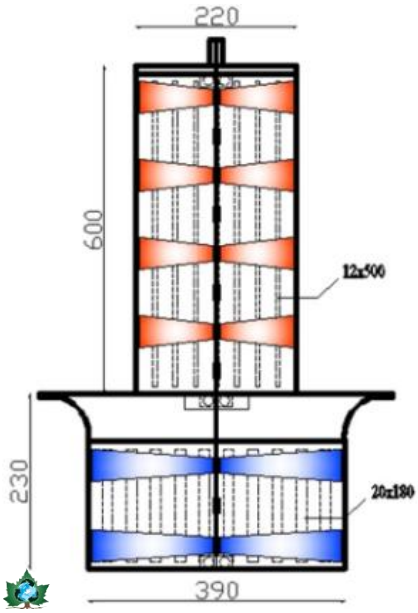


Fig. 9. Laboratory model dimensions [mm]

In order to establish the constructive elements (geometry, dimensions, and materials) of the complex system of renewable energy production in coastal areas, initially a series of experimental models were developed, which, after extensive calculations and tests, have been modified and improved [17], [18].

For example, in the first phase was designed a model whose modules (aerial and submersible) had equal diameters (Fig. 10). Following on-site testing at the Black Sea, it was noticed that its size and shape did not allow a proper exploitation. This has led to a number of changes, including:

- The new system was designed to be robust and much larger;
- The submersible module diameter is larger than the aerial module diameter;
- The material from which the deflectors were composed was made to be more resistant;
- Arrangement of the blades on the vertical axis is modified to increase the efficiency of the kinetic energy produced by their movement.

Fig. 10. In situ testing of the laboratory model - Off-shore complex for renewable energy production

In this regard, a model was designed and constructed (Fig. 6 and 11), which has been subjected to pilot tests at INCDPM Bucharest [19].

Fig. 11. The laboratory model – Off-shore complex for renewable energy production

Through these tests were modified the specific parameter values operating conditions of the system, in order to check the functionality and efficiency of the model.

In order to investigate the submersible module, different values were assigned to the amplitude of the waves generated by the equipment set out in the pilot station (Fig. 12).

Fig. 12. Measurement of wave's amplitude. Functionality of the submersible module

Table 1 shows the values of the blades rotation speed resulting from simulation of scenarios in which the magnitude of the waves varies from 6 to 12 cm. The frequency between two successive wave amplitudes is 1 second for the 6 cm amplitude and 2 seconds for the 8 and 12 cm amplitudes. Within these sets of experiments the aerial module was coupled with the submersible one.

Table 1. Values resulting from testing in the pilot station of the submersible module.

No. crt.	Amplitudes [cm]	Frequency [s]	The rotation speed of the paddle [rot/s]
1	6	1	0.13
2	8	2	0.2
3	12	2	0.3

Fig. 13. Start-up of the aerial module and measuring the amount of air velocity that is directed to the laboratory model

At the same time, at the pilot station were performed investigations on the aerial module, by developing the three scenarios in which the analysed speed rotation of the blades, in which the model was tested at the following values of the air flow speed: 1.5 m/s, 1.8 m/s and 2.4 m/s (Fig. 13).

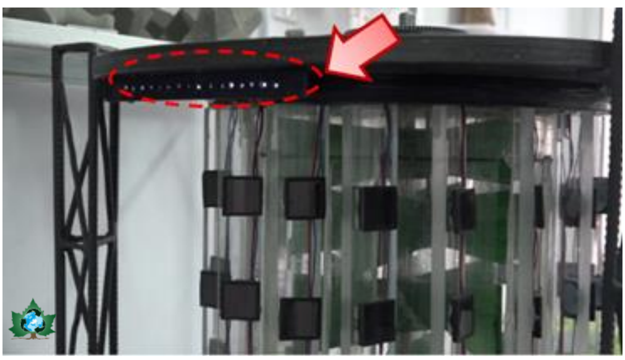


Fig. 14. The transformation of kinetic energy into electrical energy - Signaling light panel

The results of the experiments are shown in Table 2. The highest values are between the range 2.03 - 2.10 rev/s, in the context of a wind speed rotation of 2.4 m/s.

Table 2. Results obtained from laboratory tests

Scenarios	Speed of airflow [m/s]	Speed rotation of paddles [rev/s]
Scenario 1	1.5	1.65 – 1.68
Scenario 2	1.8	1.87 - 1.92
Scenario 3	2.4	2.03 – 2.10

To verify the efficiency of the laboratory model, it was equipped with a lighting system that runs on electricity produced from the conversion of kinetic and solar energy (Fig. 14).

Conclusions

From the conclusion, the importance of a concrete reinforcement design being able to sustain concrete members towards the impact explosion. The durability of the geopolymer concrete can be tested by adjusting the scaled distance during blast field event. If this ability was not analyses, blast loaded concrete structures may cause the shear cracks and engineering failure. By using fly ash as the replacement material, it was proved that better performance of the strength of concrete compared to OPC. In addition, a broader studies about awareness in public area and land defense concerns has increased the need to support the development of new and more affordable upgrade technologies The need to diminish/eliminate the negative aspects of the conventional installations for producing electricity from renewable energy sources was the starting point for the conceptual design model useful for coastal zones.

Unlike conventional installations, this system explores at the same time three potential sources of renewable energy, ensuring the highest efficiency on the surface unit, with low impact on the environment.

Due to its structural features, compared to classical installations, the off-shore complex exploits waves, solar radiation and air currents at higher yields, operating the installation continuously, day/night, with high efficiency, regardless of weather conditions. At the same time, vertical development involves complex arrangement of small areas with not significant impact on the aquatic environment. The supplied electricity depends on the size of the model.

Since the modules that make up the pattern generators are provided with slots, the airflow/water current is concentrated to the blades located on the central axis. On the length of each slot, the model is equipped with deflectors that direct the airflow and can be automatically oriented to allow the optimal system operation depending on climatic conditions. To exploit solar energy, deflectors are provided with photovoltaic cells.

Another advantage is given by the fact that the modular development and the coupling element allow the blades to move constantly, regardless of weather conditions. When the aerial and submersible modules operate simultaneously, a constant movement of the wind and hydraulic blades is ensured. In the context of extreme meteorological phenomena, the modules can be decoupled and can function independently. Also, the slots-deflectors system is programmed so that, in the case of storms, deflectors automatically cover the slots to ensure proper operation of the model.

At the same time, it should be noted that the complex system operates independently of the water level, provided with a device that can slide.

Regarding the further directions studies beyond the work that has been completed, currently are carried out activities that aim the complex system optimization. In order to increase the efficiency of the integrated installation, bioengineering solutions are being researched for the modification of the materials and the geometry of the wind and hydraulic blades.

Acknowledgments

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