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NEW METHODS OF WAVE ENERGY CONVERSION

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Abstract: *The present thesis are presented de modern technologies of wave energy conversion into electrical energy. Based on acquiring the two components of wave energy – potential and kinetic, a new conversion method is proposed, having the advantage of increasing the energy transformation efficiency and the functioning reliability of the energetic installation which is performing this technology.*

Key words: *waves, energy, wave energy, wave energy conversion, turbines, pumps.*

1. Introduction

Wave energy research has developed in the last 4 decades, stimulated on one hand by the high quantities of energy stored in oceans and, on the other hand, by the exhaustion of the quantities of fossil fuels.[1] The planetary ocean presents a large area of water currents, in a permanent move and it covers approximately 71% of the planets surface. The intensive use of fossil fuels, adding in the second half of the 20th century nuclear fuels, conducted to the appearance of several negative consequences: the pollution of the aerial and aquatic basins, acid rain formation, soil degrading, natural resources are drying out and the appearance of radioactive pollution.[2]

Although the construction of wave energy power plants is a special preoccupation for the countries which benefit from shores with powerful waves, the problem presents interest even for countries who benefit from waves of smaller magnitude.[1]

2. Modern tehnologies of converting wave energy into electrical energy

Wave energy conversion systems divide in two categories:

- shoreline and near-shore wave energy collecting installations;
- offshore wave energy collecting installations.[1]The shoreline installation category consists of: OWC (oscillating water column) which is based on a compound where waves enter, modifying the air volume in the installation, forming an oscillating column which turns a one way turbine (fig. 1). TAPCHAN is an installation which functions on the level difference principle, level difference produced by the waves passing through a channel and flooding a reservoir situated on the shoreline. This way the water accumulated in the reservoir goes back into the sea through a turbine, which in turn acts on the electric generator (fig. 2). The installation consisting of a fixed tower and a floating object produces energy thanks to the vertical movement of the floating object (fig. 3).

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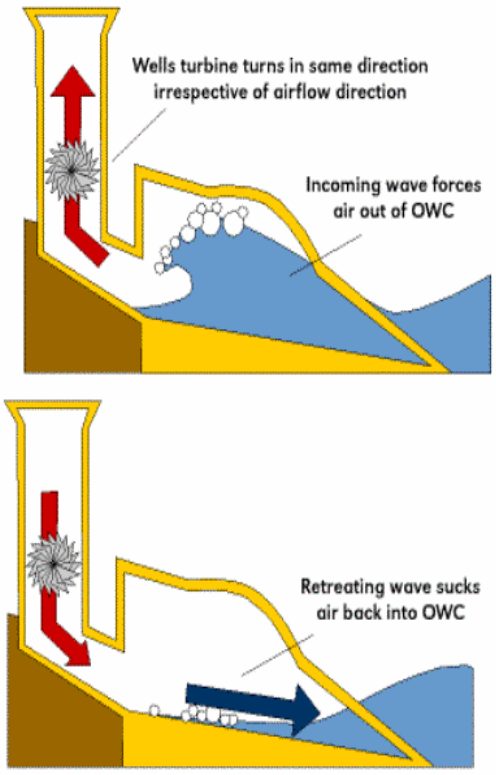

Fig.1. *OWC installation functioning principle [3]*

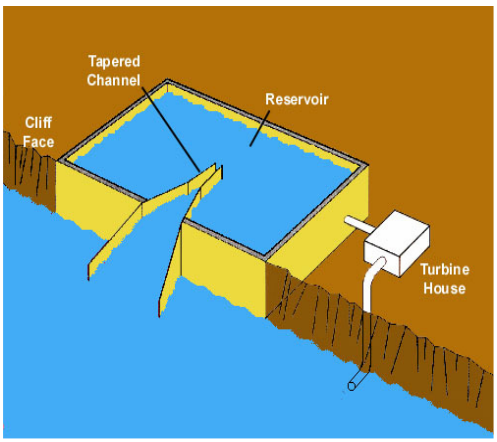

Fig. 2 *TAPCHAN installation scheme [3]*

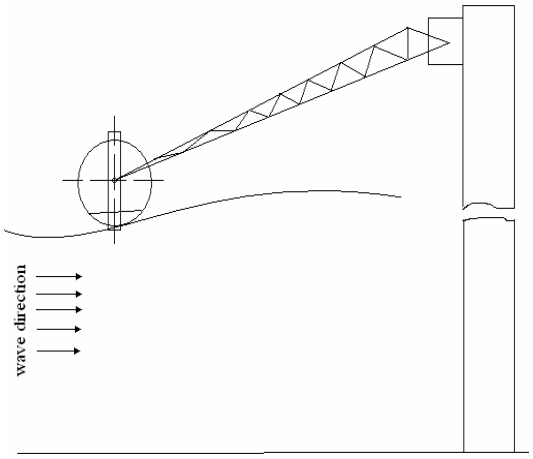

Fig. 3. *Fixed tower and floating object scheme [2]*

One of the installations which can function near the shoreline is the Wave Dragon (fig. 4).

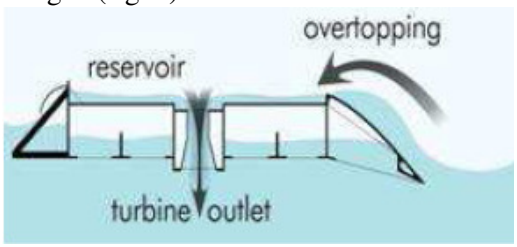

Fig. 4. *Wave Dragon installation [4]*

In the offshore installations category we can include: Salter's Duck, Pelamis Wave Energy Converter, The Archimedes Wave Swing, Wave Roller System, Bristol Cylinder.[4]

One of the installations which have a relative good efficiency compared to the other offshore installations is Pelamis (fig. 5), which consists of several large pipes connected to each other through a series of joints, who, thanks to the angular inclines formed by the waves, act like closed circuit oil pumps. In term, the pumps act on hydraulic turbines connected to electrical generators.

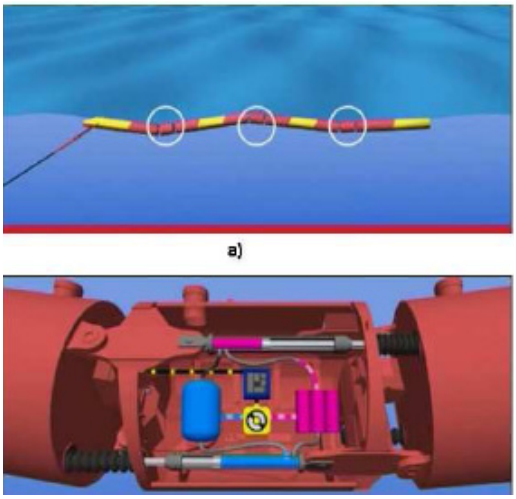

Fig.5.*Pelamis installation [5]*

Wave energy conversion installations can be characterized by:

- taking over the wave energy, realized through: the air oscillating column formed by the sea water; floating objects of different shapes and sizes; oscillating panels; the accumulation of water rised by waves into a reservoir;
- the acting of turbines which can be realized with the aid of: air; sea water; hydraulic oils in a closed circuit;
- the acting of electrical generators with the aid of: air turbines; hydraulic turbines; mechanical machines having floating objects as an action element.

The wave energy conversion installations could work in parallel to other energy conversion systems like solar energy, wind energy or heat pumps. For example, solar energy can be collected with a good efficiency in the OWC and TAPCHAN installations because the areas covered by these installations are relatively wide.

Installations based on wind energy can be successfully used offshore, because the intensity of the air currents on the sea surface is strong, giving a better efficiency in comparison to the shoreline installation using the same principle.

3. Wave energy conversion system

The installation for wave energy conversion [6] (fig. 6 and 7) consists of a floating cylinders structure **(1),** which is anchored in the symmetry centre to the bottom of the sea, floating freely or is tied to a ship. The floating cylinders **(1)** are mounted in such a way that they have the possibility to rotate on their longitudinal axle **(2)** and have on both ends connecting rods **(3)** perpendicular to the longitudinal axle **(2)**. This way, one end of the connecting rod **(3)** is rigidly connected to the end of a floating cylinder **(1)** and the other end of the connecting rod **(3)** is rigidly connected to the longitudinal axle **(2)** of the neighbor floating cylinder **(1)**.

The mechanisms of transforming the relative alternative rotating movement of the floating cylinders **(1)** relative to the longitudinal axle **(2)** consist of (fig. 8)

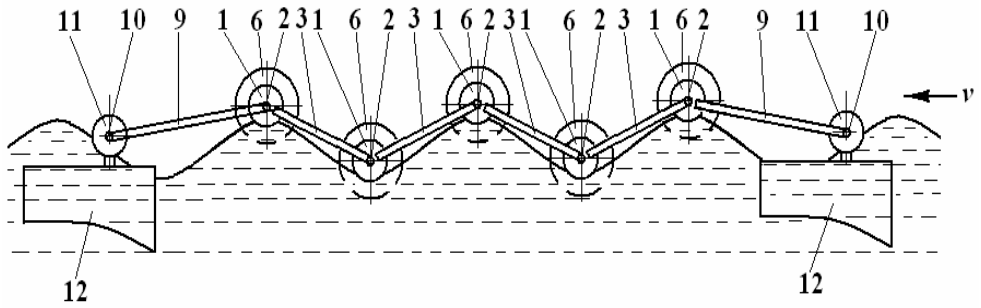

Fig. 6. *Wave energy conversion installation, side view*

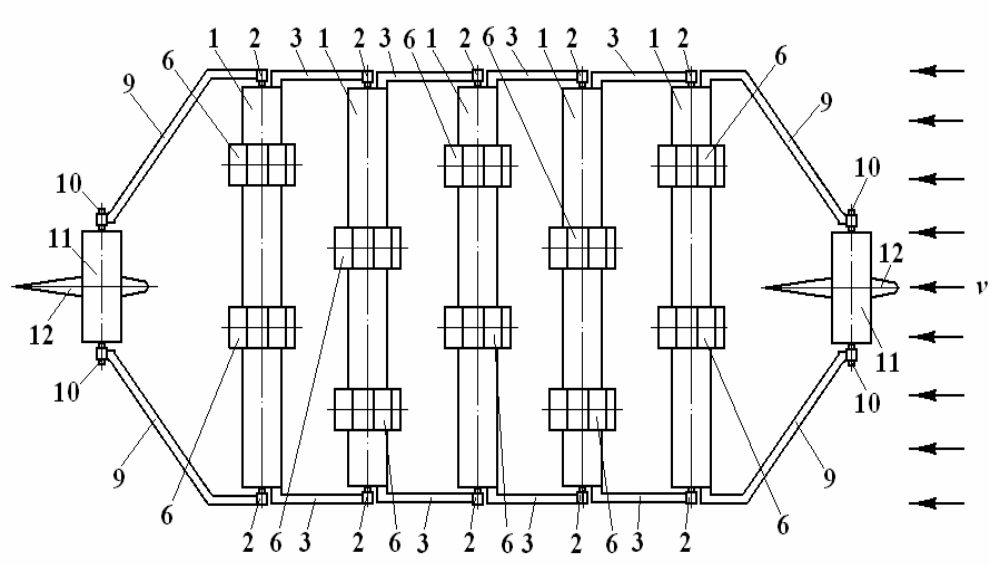

Fig.7. *Wave energy conversion installation, top view*

multiplying gears and transmissions who transform the relative alternative movement into a single way rotation movement and on the ends of these transmissions are the electric generators **(4)**.

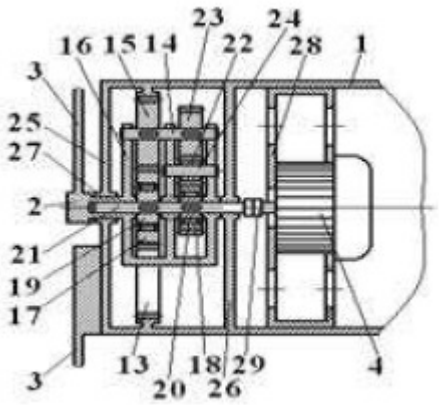

Fig.8. *Cinematic scheme of the transformation mechanism of the relative alternative rotation movement of the floating cylinders relative to the longitudinal axes.*

On the same axis with each floating cylinder **(1)** are mounted water wheels **(6)** with helicoids blades **(7)** with ear drums **(T)** –fig. 9, rigidly installed on rotation axes **(5)** having the rotation possibility relative to the floating cylinders **(1)**, water wheels which are oriented in the same direction as the wave **(V)** propagation **(*v*)**.

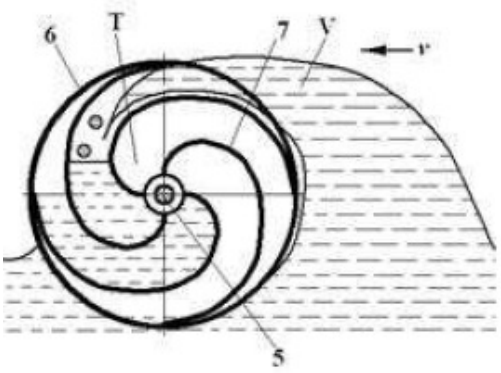

Fig.9. *Section A-A through the water wheel fig.7*

The water wheels **(6)** are connected by a set of extra multiplying gears (fig. 10) to extra electric generators **(8)**.

The marginal floating cylinders with the longitudinal axle **(2)** are connected to the cross beams **(9)** with the longitudinal axes **(10)** of the extra floating cylinders **(11)**, on

which the rudders are suspended **(12)** for the orientation of the cylinder structure **(1)** with the longitudinal axle **(2)** perpendicular on the wave propagation direction ***(v)***.

The multiplying gears (fig. 8) of the transformation mechanism of the relative alternative rotation movement of the floating cylinders **(1)** relative to the longitudinal axes **(2)** and the extra multiplying gears (fig. 10) are executed as a planetary transmission, with the center wheel **(13)** mounted rigidly on the inside wall of the floating cylinder **(1)**, on the same axis as the longitudinal axle **(2)** of the floating cylinder. The satellite **(15)** rotation axle **(14)** is mounted on a trident shaped crank **(16)**, rigidly connected to the longitudinal axle **(2)** of the floating cylinder **(1)** – fig. 8 or to the rotation axle **(5)** of the water wheels **(6)** –fig.10.

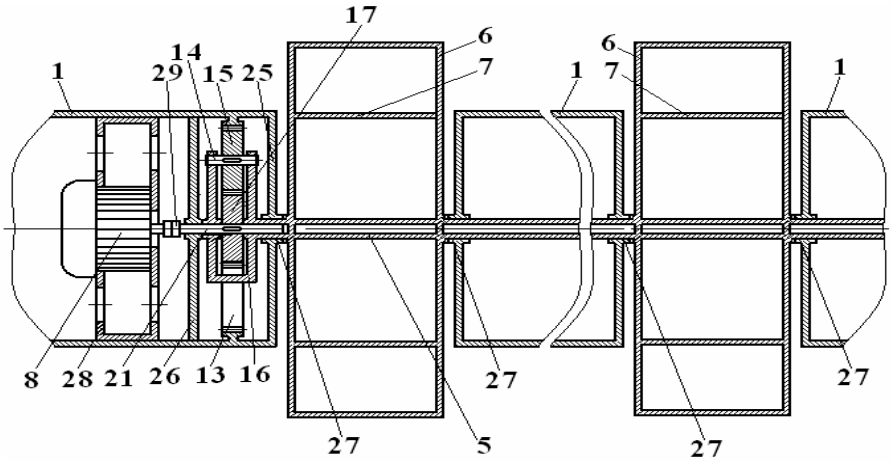

Fig.10. *Cinematic scheme of the extra multiplying gear system coupled to the water wheels*

The gears which transform the alternative rotation movement in one way rotation movement have the same construction (fig. 9), consisting of two spiked wheels **(17)** and **(18),** mounted on one way couplings **(19)** and **(20)** cu opposite ways of rotation (fig 11 and 12), rigidly fixed on the exit axle of the transmission which transforms the alternative rotation movement in to one way rotation movement, one the same axis as the longitudinal axle **(2)** of the floating cylinder **(1)** with the possibility of independent rotation relative to the longitudinal axle **(2)**. The spiked wheel **(17)** is connected to the satellite **(15)** of the multiplying gear system, and the spiked wheel **(18)** with the intermediary spiked wheel **(22)**, which is connected to the extra satellite **(23)**, rigidly mounted on the rotation axle **(14)** of the satellite **(15)** from the multiplying gear system.

For the rotating speed to concur the spiked wheel **(17)** has the same number of teeth as the satellite **(15)** from the multiplying gear system and the spiked wheel **(18)** has the same number of teeth as the extra satellite **(23)**. The intermediary wheel **(22)** is mounted in such a way that it has the possibility of rotating around the axle **(24)**, fixed on the crank **(16)**. The exit axle **(21)** of the transmission which transforms the alternative rotation movement in to one way rotation

movement sits on two bearings mounted on the walls **(25)** and **(26)** of the floating cylinder **(1)**. The bearing **(25)** on the wall is fitted with a seal **(27)** so the water doesn't enter in the floating cylinder **(1)**. The electric generators **(4)** and **(8)** are rigidly fixed on the frames **(28)** and are connected using the coupling **(29)** to the exit axle **(21)** of the transmission which transforms the alternative rotation movement in to one way rotation movement – fig. 8 or to the axle **(21)** of the multiplying gear set of the water wheels **(6)** – fig. 10.

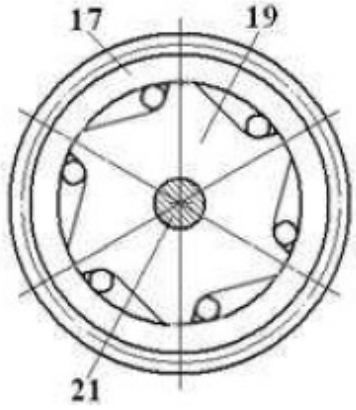

Fig.11. *One way couplings with oppositeway of rotation, front view*

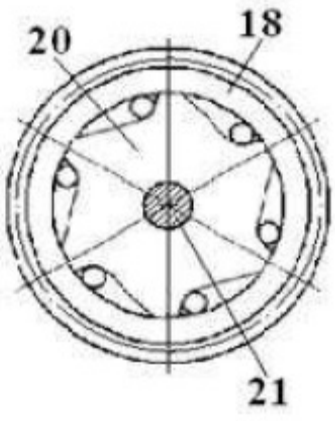

Fig.12.*One way coupling with rotation way opposite to the one in fig.11, front view*

The installation for wave energy conversion works this way: under the action of the waves which propagate in the arbitrary direction **(*v*)** the rudders **(12)** suspended on the extra floating cylinders **(11)** will orientate, through the crossbeams **(9),** the floating cylinders structure **(1)** with the longitudinal axes **(2)** perpendicular on the wave's propagation direction **(*v*)**. In this position, under the action of the waves, the floating cylinders **(1)** will oscillate having the same oscillating amplitude as the waves. Through the connecting rods **(3)** the alternative oscillating movement will be transmitted, on one hand, to the neighbor floating cylinders **(1)** and, on the other hand, to the longitudinal axles **(2)** of these cylinders. This way, the bodies of the floating cylinders **(1)** will have an alternative relative rotation movement relative to the their longitudinal axles **(2)** and will have torque momentums high enough to multiply this movement until it reaches the nominal number of revolutions of the generators **(4)**.

Through the cranks **(16)**, rigidly connected to the longitudinal axles **(2)**, on one hand, and through the center wheels **(13)** rigidly connected to the floating cylinders **(1)**, on the other hand, the relative torque momentums will be transmitted with multiplied number of revolutions to the satellites **(15)**, which are on the same gear system as the center wheels **(13)** and are rigidly mounted on the axles **(14)** which rotate in the cranks **(16)** bearings. The satellites **(15)** rotation movement will be transmitted to the spiked wheels **(17)** which are on the same gears system as the satellites **(15)**. This movement will then be transmitted to the satellites **(15)** number of revolutions, because of the fact that the number of teeth on the spiked wheels **(17)** is equal to the number of teeth on the satellites **(15)**. Depending on the way the spiked wheels

(17) turn the one coupling will engage the spiked wheels **(17)**, if, for example, their rotation direction is clockwise, or the spiked wheels **(17)** will turn without engaged anything, if their rotation direction is anti-clockwise. In this case, the rotation movement from the satellites **(15)**, parallel transmitted through the axles **(14)** of the extra satellites **(23)**, to the intermediary wheels **(22)** to reverse the rotation direction, will be taken over by the spiked wheels **(18)**, which with the aid of the one way couplings **(20)** will be coupled to the rotation axles **(21)**, and then , through the couplings **(29)**, the rotation movement will be transmitted to the electric generators **(4)**. The speed of the spiked wheels **(18)** will be the same as the speed of the satellites **(15)** and **(23)**, because the fact that the number of teeth on the spiked wheels **(18)** is the same as the number of teeth on the extra satellites **(23)**. This way, even if the spiked wheels **(17)** and **(18)** will turn alternatively, but always opposite to each other, the axles **(21)** rotation direction will be the same, for example, clockwise.

This way the potential component of the mechanic wave energy is converted.

The kinetic component of the mechanic wave energy is converted using the water wheels **(6)**. Due to the helicoid shape of the blades **(7)** like an ear drum (fig. 8), the wave ridges **(V)** will ark over the blades **(7)** and will fill up the drums **(T)** of the wheels **(6)** with water. This way on the back end of the wheels the drums will be filled with water. The torque momentum of the wheel will be created by the interaction of the water from the waves **(V)** in a swirl motion, on one hand, and on the other hand by the one way momentum created by the water from the drums **(T)** behind the wheels **(6)**. On the front end of the wheels **(6)** the water will drain back into the sea.

The rotation movement of the water wheels **(6)** will be transmitted through the rotation axles **(5)** to the cranks **(16)** of the planetary multiplying gear system. Through the cranks **(16)**, rigidly connected to the rotation axles **(5)**, the relative torque momentums between the water wheels **(6)** and the floating cylinders **(1)** will be transmitted with multiplied number of revolutions to the satellites **(15)**, rigidly mounted on the axles **(14)** which revolve in the cranks **(16)** bearings and connected to the center wheels **(13)**, rigidly connected to the floating cylinders **(1)**. The rotation movement of the satellites **(15)** will be transmitted to the spiked wheels **(17)** connected to the satellites **(15)**. This movement will be transmitted to the satellites **(15)** number of revolutions, because of the fact that number of teeth of the spiked wheels **(17)** is the same as the number of teeth on the satellites **(15)**. Then through the rotation axles **(21)** and the couplings **(29)**, the multiplied revolving movement will be transmitted to the electric generators **(8)**.

When the rotors of the generators **(4)** and **(8)** rotate, they will generate electric current and this way the conversion of the mechanic wave energy into electric energy takes place. The electric energy will be transmitted through an underline cable to the consumers.

This way the proposed installation, thanks to the fact that it converts both the potential component as well as the kinetic component of the mechanic wave energy and also because of the improvement of the construction compared to the known installation, ensures higher conversion efficiency.

4. Conclusion

It has been highlighted the fact that reusable sources must occupy an important place in energy production, because of the limitation of fossil fuels and because of the hazardous effects that these fuels have over the environment.

A few installations that convert wave energy in to electric energy have been presented.

The way in which the installations that convert wave energy can function as a hybrid with other installations which transform reusable energy has been discussed.

An installation of converting wave energy is proposed, which has the property of converting both the potential and kinetic components of wave energy, this way the installation has a high efficiency rate.

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