Chapter

Hydro Power Tower (HYPOT)

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Abstract

Humanity has used the power of falling water for centuries to produce electrical energy, but there have been no significant changes in technology. Marine Energy has received an explosive development. Traditional technologies are passive and have low efficiency. It is not possible to use the effect of falling water in the ocean. The chapter considers the technology, which allows to convert not only the kinetic energy of a moving horizontal flow, but also the potential energy of water hammer in a combination of pressure drop between layers of water that have different hydrodynamic characteristics. This is a high efficiency due to the use of the Pitot-Prandtl tube principle and Bernoulli's law and in combination with the effect of raising the water of the hydraulic ram. The calculations are based on computational fluid dynamics (CFD) methods. It is known that 94% of incoming solar energy is converted into underwater currents and only 6% - on the surface. Therefore, the proposed technology can be highly competitive in relation for example to Orbital Marine Power (OMP) project and another known offshore wind and wave power plants which convert only the kinetic energy of the surface air and sea currents.

Keywords: Marine Energy, Water hammer, Shock wave, Pulsating flow, Pitot tube

1. Introduction

The formulation of the project theme includes general information about the facility as a new source of renewable energy for the ocean.

This is an underwater gravitational energy technology, which is one of the most promising generating devices due to the significant potential of generating electrical energy, as it converts a large volumetric part (almost 94%) from all the potential solar energy captured by the oceans.

A hydroelectric power plant perceives the kinetic energy of currents and the potential energy accumulated by it due to water hammer and pressure drop between the layers. It artificially creates a rising whirlpool in the open sea. At the same time, the gift wave from the water hammer propagates through the two-phase hyperbolic project HYPOT and increases the pressure - in the positive direction, when falling - in the negative direction. This occurs when there is a sharp change in the direction of the current in the neck of the tower. The destructive effect of this phenomenon is associated with the inability of the fluid to contract smoothed out by the hyperbolic curve.

The chapter presents the main assumptions and results of the calculation of the digital twin, as well as the design methods of the HYPOT project. **Figure 1** shows a general view of the hydroelectric power plant of the cyclone action.

The HYPOT project in the complex can convert the kinetic energy of tidal and bottom flows, as well as the potential energy of pressure drop at different salinity

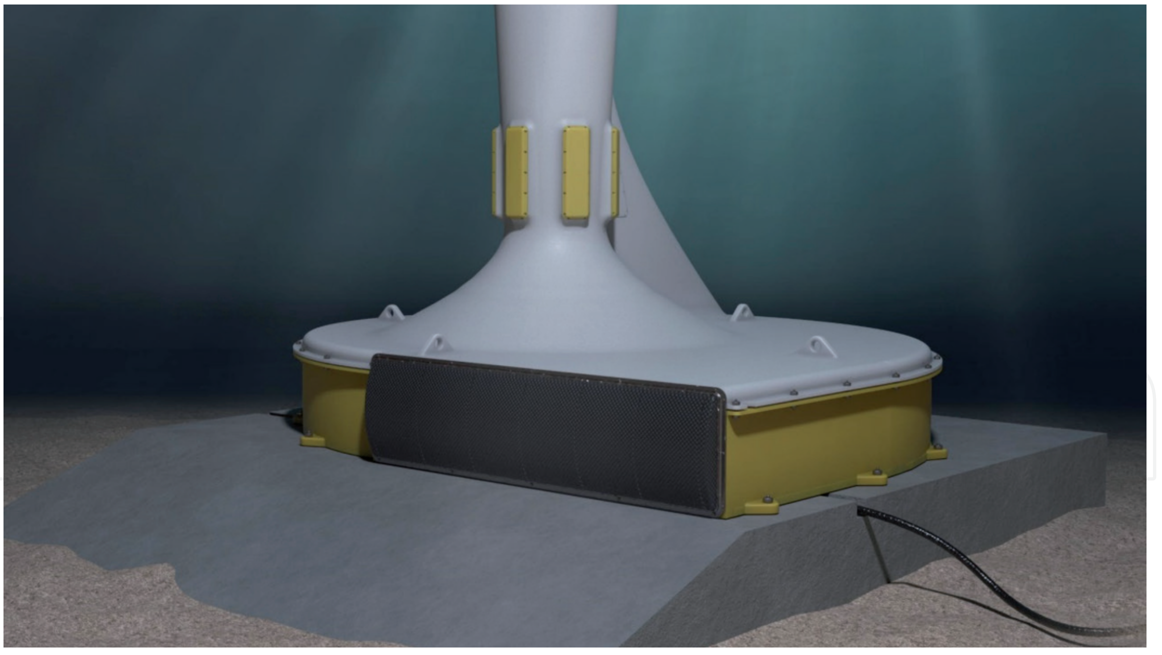

Figure 1.
Underwater hydroelectric power plant of cyclone action.

and water temperature. With the help of water hammer, the kinetic energy of the moving liquid is transferred into the potential energy of the resting liquid. However, such a transition is not instantaneous, but proceeds at a certain speed, depending on the properties of the liquid and the geometry of the pipeline. The HYPOT enclosure has a two-phase hyperbole geometry that reproduces the narrowing configuration in the center of the torus.

This is done by analyzing the vector of motion of the lifting flow for the maximum approximation to natural conditions. With the tower version, the tower creates the initial necessary pressure for the operation of pulse devices (on the principle of "water hammer"), so the project refers to a gravitational-pulse hydroelectric power plant, since the potential energy of water is the gravitational energy accumulated in it.

2. Theoretical prerequisites for calculation

Calculations of the HYPOT prototype in the ANSYS software package clearly proved the effect of water hammer into the neck of the tower on the increase in flow [1–3]. **Figure 2** shows spatial scheme of HYPOT digital twin for calculation in ANSYS as opposed to simple OMP [4]. The diagrams in **Figures 3** and **4** show how the pressure vector increases as the current in the collector moves to the neck of the tower, where there is a sharp pressure drop of 26.5 times, and the jump in the value of the flow vector increases respectively to 87.54 m/s due to water hammer. The calculation is made with the assumption that the entire volume of the incoming water flow flows into the collector. In order to find the balance of the incoming water into the collector and bypass it, it will be necessary to further solve the problem of multipoint calculation of the hydroelectric power plant, including the maximum possible sphere of water surrounding the station, in order to understand the losses at the entrance to the collector. Since the station works in general with water hammer and the release of water through the upper nozzle, the assumption that the entire volume of water will fall into the collector has a small error due to strong centripetal and forward motion along the current upwards in a hyperbolic tower.

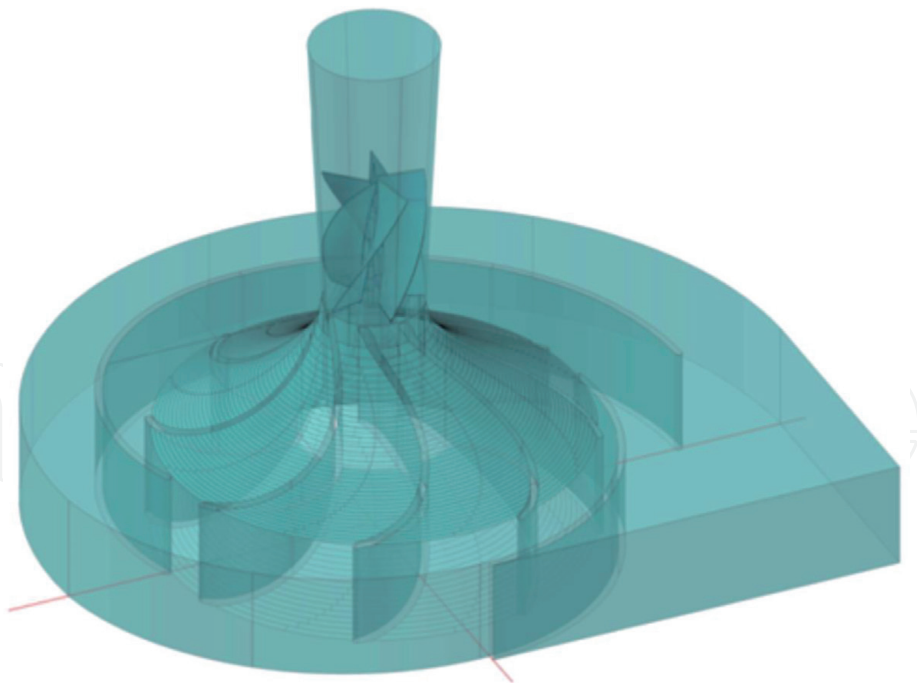

Figure 2.
Digital twin.

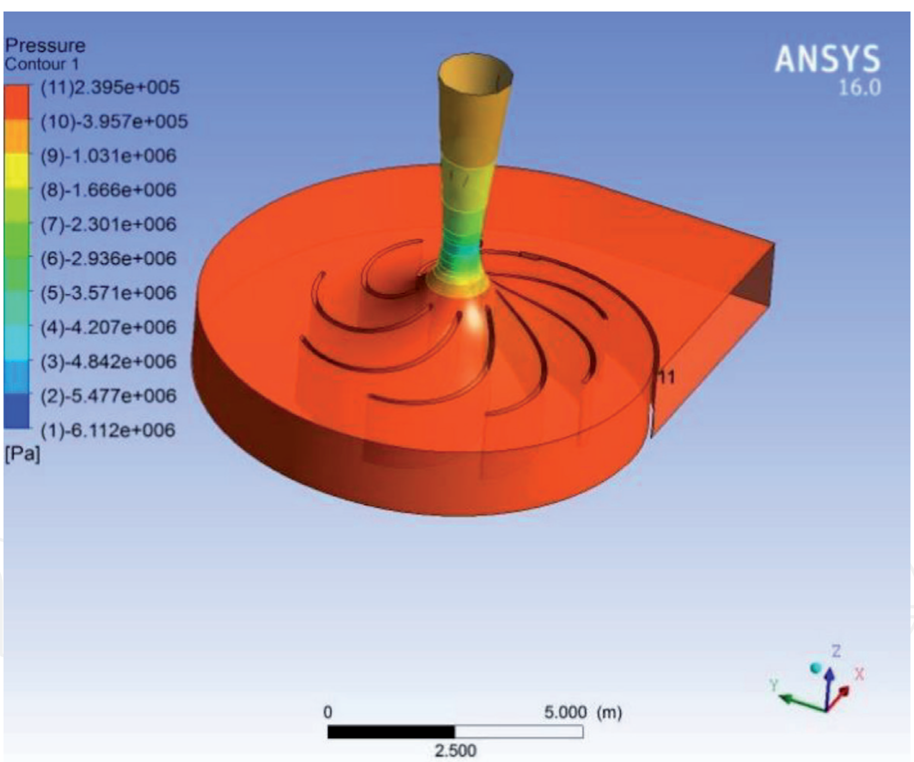

Figure 3.
Pressure at the speed of 4.5 m/s and inlet water flow of 32,4 m^3*/s.*

Hydraulic shock at HYPOT is a short-term, but sharp and strong increase in pressure in the collector with a sharp braking of the fluid flow moving through it from the outside. The phenomenon of water hammer [5] here is creative - it is with its help that an impulse is given to the water intake, which then obeys Bernoulli's law of communicating vessels rises up, throwing water from the nozzle of the tower under high pressure.

First of all, it is necessary to take into account the high speed of the water hammer process. Since the speed of movement of the boundaries of zones with different

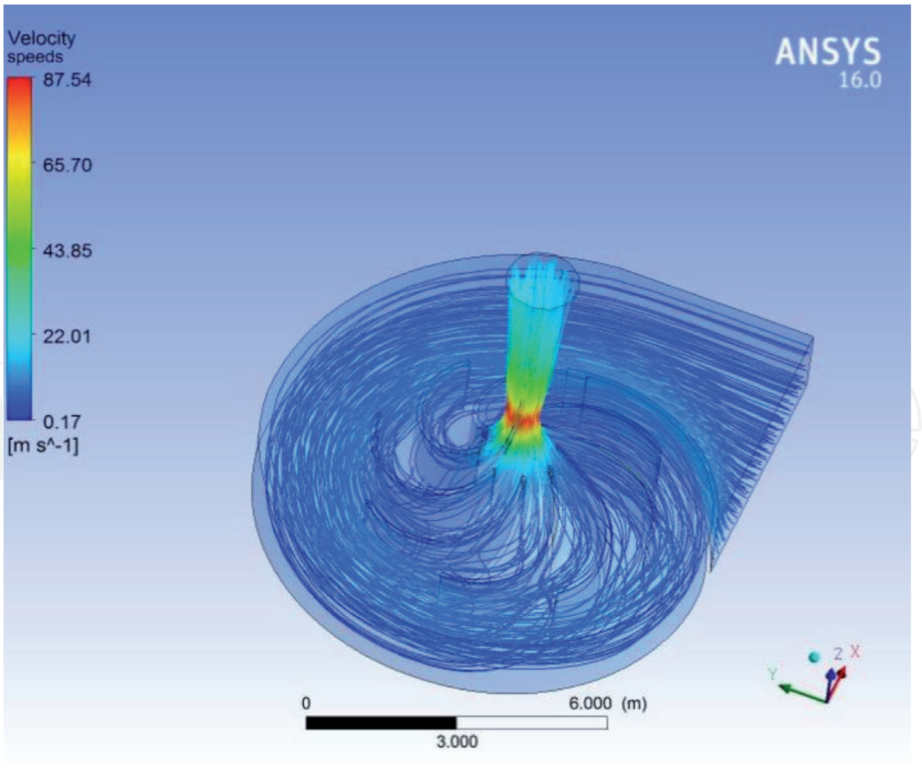

Figure 4.
Volocity speeds at the water speed 4.5 m/s and the incoming water flow of 32.4 m³/s.

pressures at high rigidity of the body and neck is determined by the speed of propagation of elastic deformations in the liquid, i.e. the speed of sound, everything happens in a very short time.

As the size of the tower increases, the power of the water hammer increases significantly, and at the same pressure at the entrance to the tower, this growth is usually steeper than the linear dependence. Here we will consider the qualitative reasons for this behavior (quantitative results automatically follow from the calculations in the ANSYS program given in the following sections of this page).

However, with an increase in linear mass sizes (and, consequently, kinetic energies at the same rate) increase in proportion to the volume, i.e. the cube of their change, and the friction losses against the walls of the pipe are proportional to the contact area, that is, the square of the size change. Thus, the specific loss of energy per friction per unit mass of the liquid decreases, which means that with the same driving force (external pressure), the flow rate increases, and hence the pressure jump at the time of stopping.

It should be noted that the pressure jump during water hammer does not depend on the initial pressure that caused the liquid to move through the tower, but depends only on the speed obtained by it. This means that the acceleration of a liquid with a relatively high pressure in a short time can be replaced by a longer acceleration under the influence of lower pressure. However, it will not be possible to indefinitely reduce the acceleration pressure: first, in real conditions, the low pressure already at a not too high flow rate will all go to compensate for hydraulic friction; secondly, even for super fluidity, there is a limit to the maximum speed that the flow can reach at a given head at the entrance to the tower in accordance with Bernoulli's equation.

However, it is this circumstance that allows hydraulic rams to raise the fluid to a height many times higher than the difference in levels that leads them.

Finally, it should be noted that the vacuum, up to the almost complete absence of pressure with a strong water hammer, does not mean that at this stage the liquid leaves the entire tower pipe. This only means that the liquid ceases to put pressure on its walls. In reality, the void is formed only in the separation zone near the neck of the tower - in the same place where there was a water hammer with a sharp change in flow.

Where does the fluid accelerate?

First of all, it is necessary to find out where the acceleration of the liquid occurs - in the tower or outside it? The continuity equation gives an unambiguous answer: inside the tower of the unchanged cross-section, the flow rate is also unchanged, which means that all the acceleration occurs in the tank in front of the tower! It is easy to imagine by observing the discharge of water from the bath - the "funnel" over the drain hole is due to the zone of acceleration of water, which is located in the volume of the bath itself, and in the drain pipe the water speed no longer changes. Therefore, the water hammer energy is due to the fact that the entire volume of water moves in the pipe at the same speed.

Involving fluid in motion outside the tower.

Involving the fluid filling the tower in the movement beyond it.

The paler color in the chart shows areas at a higher rate. Gradations are shown conditionally, the increase in speed is sharp.

Shock wave damping [6].

As the liquid accelerates before entering the tower when the fluid in the collector has stopped as the result of water hammer, the liquid that has already gained some speed near the manifold entrance is forced to stop. This stop causes an increase in pressure around the inlet to the tower, which is often interpreted as "shock wave exit from the pipe".

However, the pressure drop is large, and therefore the liquid moves faster. Then the pressure outside the tower drops rapidly, and the speed of movement of the liquid outward also increases rapidly.

Finally, it should be recalled that all the processes described here occur very quickly in microseconds!

Above we have considered the water hammer from the "traditional" mechanistic positions.

It should be noted that for a short time, water hammer puts the substance in extremely extreme conditions - the pressure can increase by hundreds or even thousands of atmospheres, which corresponds to conditions at a depth of tens of kilometers. But even if the pressure does not grow very much (by dozens of atmospheres, or even just by several atmospheres), the rate of pressure changes for each particle of matter that falls under the influence is very high - 1012 Pa/s or more. It is quite comparable, and even exceeds the rate of change in pressure during explosions. At the same time, the gas or plasma environment formed during explosions is very compressible - it "absorbs" the impact, and a little further from the epicenter the pressure rises much more smoothly. But during water hammer, due to the low compressibility of liquids and the high rigidity of the wall material, this ultra-fast pressure jump affects almost the entire volume involved in the water hammer. Such sharp jumps in pressure correspond to gigantic accelerations and inhibition of particles of matter when the shock wave front passes through them. True, they last nano- and picoseconds, so the total displacement of liquid particles is small and usually is, in accordance with its low compressibility, micrometers or nanometers. However, by the standards of atoms and molecules, these shifts are very large, and the resulting forces are also significant.

For example, Carré (1705) observed a curious phenomenon: a bullet fired into a wooden box filled with water exploded. A shock bullet, transmitting a large pulse to the water, generates a shock wave that tears the walls [6].

3. Analytical calculation

The subject of these applied research and experimental developments planned for the project is, first of all, the determination of the forces of intermolecular interaction of water in the stream at different pressures and ambient temperatures and when using a cyclone amplifier. Ocean currents carry kinetic energy obtained from solar radiation, entering the collector, the current experiences a sharp drop in pressure on the rise into the neck of the tower and increases the speed due to water hammer, which closes the chain reaction of overcoming gravity and ejecting water through the nozzle of the tower.

Depending on this, the flow rate and volume are calculated to generate electrical energy in a two-phase hyperbolic housing by a spiral turbine, which ultimately

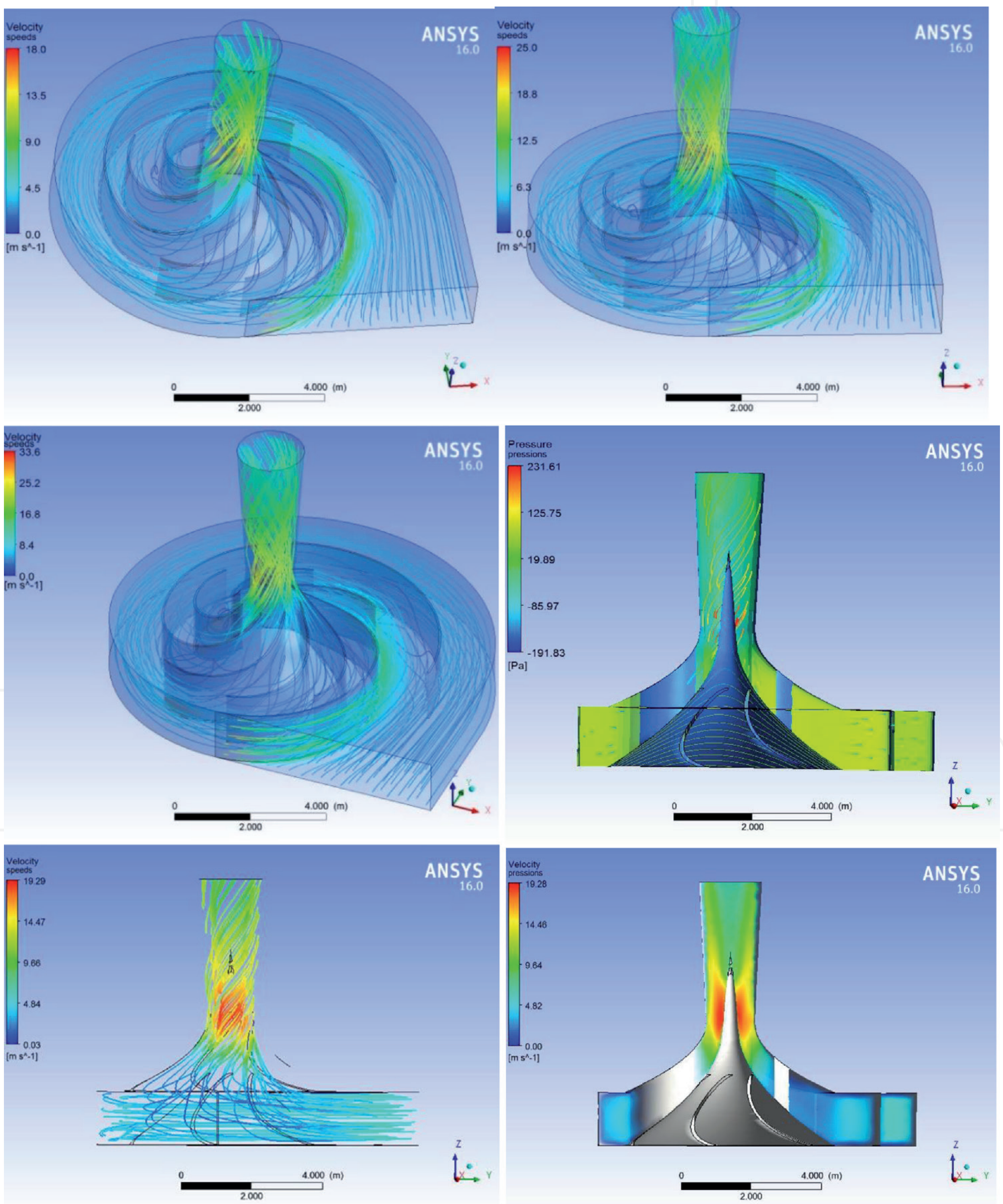

Figure 5.
The calculation diagrams of the HYPOT's distribution of velocity and pressure at flow rates m/s in the collector: 1.8; 2.5; 3.2.

z	7,5					
R (M)	Vz	Wabs	Vt	Beta	phi	h jet (m)
0,2	-0,87	1,28	0,94	−42,82	−0,93	0,014
0,3	1,57	2,66	2,15	36,17	0,73	0,044
0,45	4,87	6,22	3,87	51,53	1,26	0,423
0,5	5,75	7,19	4,32	53,10	1,33	0,590
0,7	9,17	10,91	5,91	57,19	1,55	1,501
0,9	10,87	12,85	6,85	57,77	1,59	2,109
z	3,5					0,219
R (M)	Vz	Wabs	Vt	Beta	phi	h jet (m)
0,2	13,37	19,15	13,71	44,28	0,98	3,190
0,3	13,58	18,13	12,01	48,51	1,13	3,291
0,45	12,8	17,2	11,49	48,09	1,11	2,924
0,5	12,7	16,56	10,63	50,08	1,20	2,878
0,7	11,85	14,83	8,92	53,04	1,33	2,506
0,9	10,87	12,85	6,85	57,77	1,59	2,109
Z	4,6					0,378
R (M)	Vz	Wabs	Vt	Beta	phi	h jet (m)
0,2	8	13,27	10,59	37,08	0,76	1,142
0,3	10,35	14,78	10,55	44,45	0,98	1,912
0,45	11	14,8	9,90	48,01	1,11	2,159
0,5	10,8	14,53	9,72	48,01	1,11	2,081
0,7	9,36	12,82	8,76	46,90	1,07	1,563
0,75	9,83	12,5	7,72	51,85	1,27	1,724

Table 1.
Results of preliminary calculations of the tower for the HYPOT project.

determines all energy production. Based on the effect of Italian physicist Giacomo Batista Venturi, Daniel Bernoulli Low, Henry Pitot tubes [7] and the Navier–Stokes equation for incompressible liquid, using ANSYS software for the hydropower tower calculation scheme. **Figure 5** shows the calculation diagrams of the HYPOT's distribution of velocity and pressure at flow rates m/s in the collector: 1.8; 2.5; 3.2.

Preliminary calculations of the tower at a depth of 30 meters showed the following results, which are summarized in **Table 1**.

4. Testing the digital twin of the lower

Based on the preliminary calculations given in Chapter 2, the international HYPOT project developed a prototype of a digital twin hydroelectric power plant for installation in the Strait of Messina off the coast of Sicily (Italy).

The international project included the results of the calculation of an underwater hydroelectric power plant with a tower height of 7.5 m. Below is **Figure 6** of the HYPOT's section of the power plant developed as part of the project.

As you can see from the diagrams above, the initial flow is not essential. for generated hydraulic energy. The main role is played by the pressure difference between the layers and the configuration of the intake manifold, which provides conditions for the occurrence of water hammer and obtaining the strongest acceleration in the neck of the tower. In addition, various sections from round to elliptical were tested from view of the analysis of the hydraulic power of the plant and the results are summarized for the selection of tower sections **Figure 7**. These graphs, being a purely empirical document, should not be distributed in one form or another, in addition, they are valid not only for choosing the configuration of the tower section.

The diagram below in **Figure 8** shows the kinetic energy levels available in the tower. We can see that 41% of this energy is still present at the exit of this tower, the rest is spent on walking from the pass to the exit. This means that up to 41% of the total energy entering the tower can be used to convert into a vortex turbine (the results are deposited from ANSYS CFD). The red curve is something that would be desirable to implement with a turbine so that it can return the maximum energy obtained in both images.

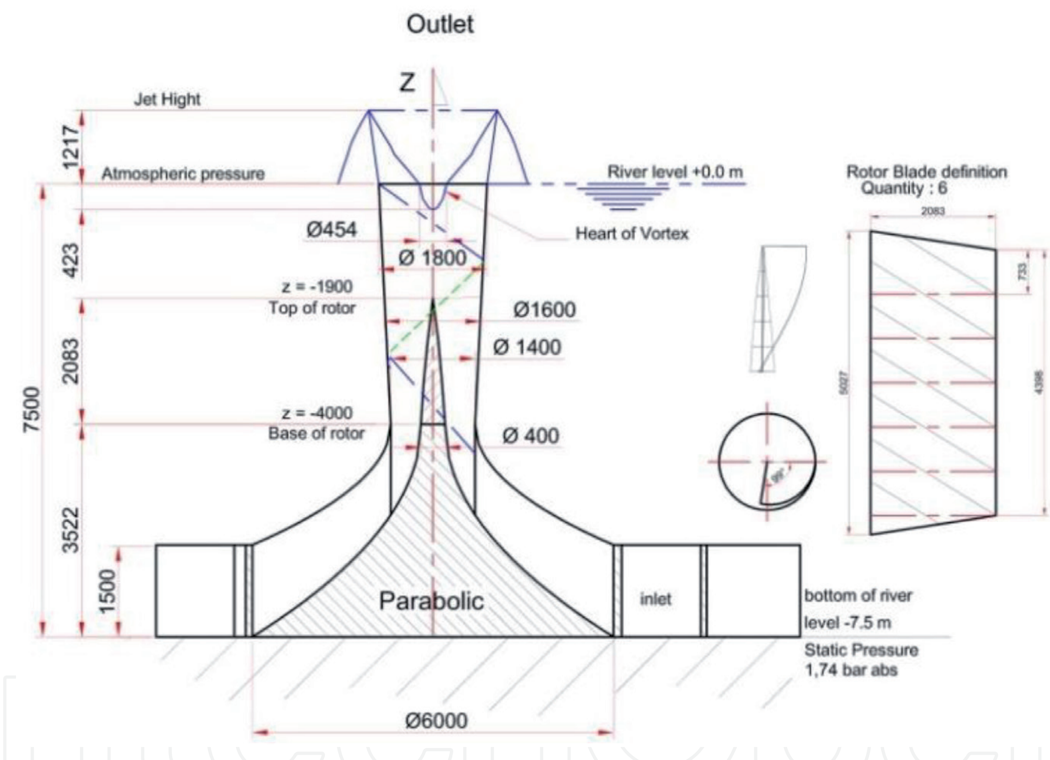

Figure 6.
The HYPOT's section of the power plant.

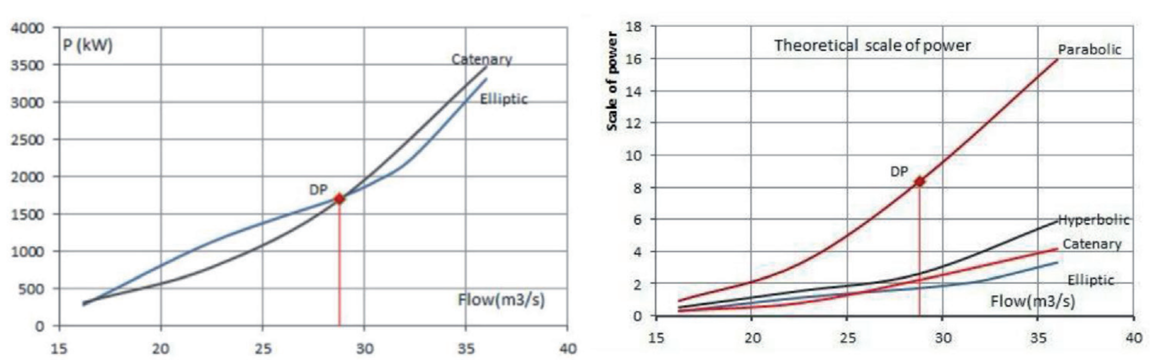

Figure 7.
Analysis of hydraulic power.

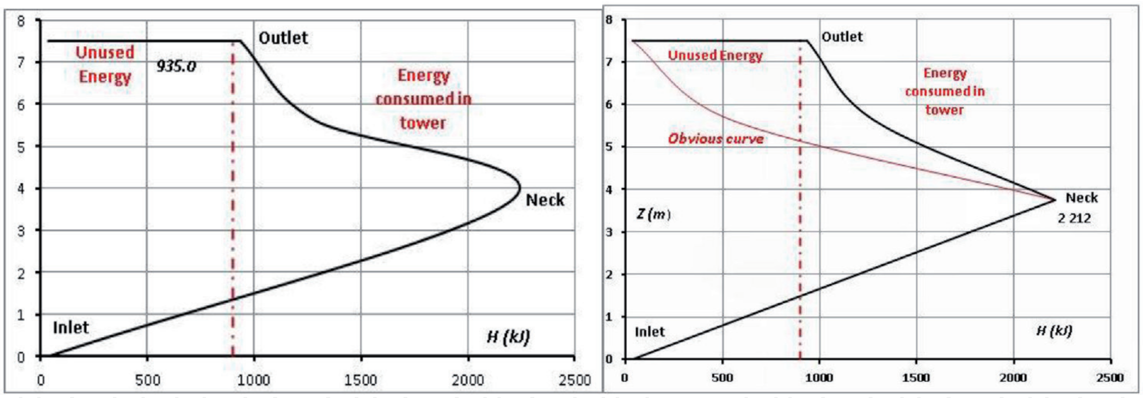

Figure 8.
Analysis of kinetic energy levels.

Figure 9.
Prototype of the HYPOT model in 1:3 scale.

The prototype of the HYPOT's model of scale 1:3 is designed to test the principle of operation of the entire system in the conditions of the mouth of the river flowing into the open sea, shown in **Figure 9**.

The subject of these studies is the problem of creating a new technology for the stream generation of powerful products for underwater hydroelectric power plants and hydrogen production services. The subject of the project is current scientific research (theoretical and experimental), as well as the development of an experimental technical and technological solution for the production of electrical energy in an artificial whirlpool with the possibility of obtaining hydrogen to replenish the peak load of the power plant and use oxygen waste to clean the polluted ocean.

Thus, the subject of the application reflects the research essence and nature of the work (subject and object).

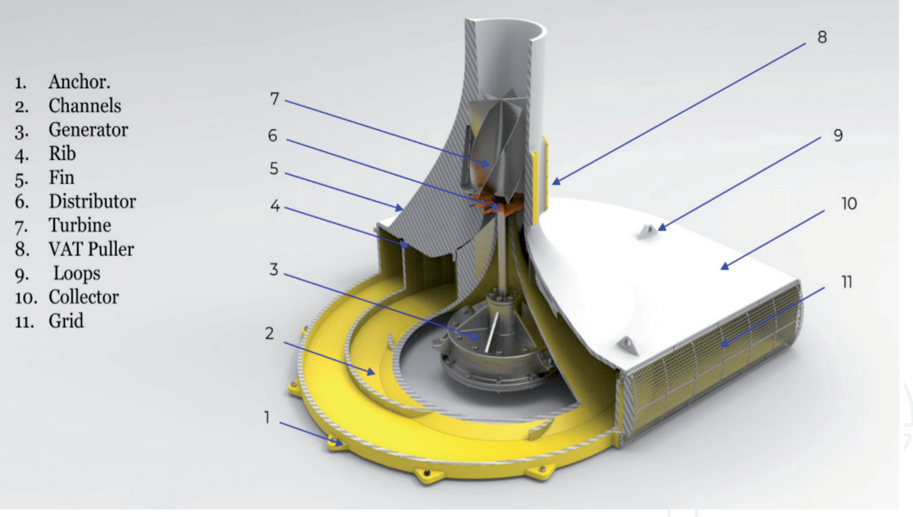

Figure 10.
Industrial project of HYPOT.

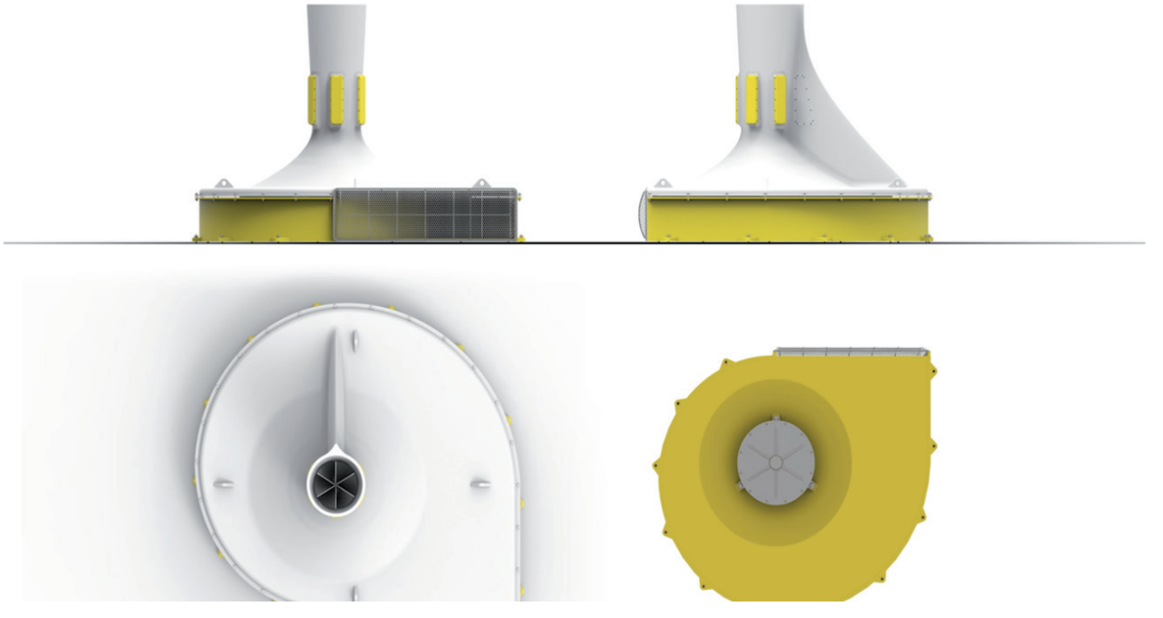

Figure 11.
Industrial prototype of the HYPOT in the Cartesian coordinate system.

In the following sections, the wording to the description of the subject of the proposed work, as well as the characteristics of the composition of the work and the scientific and technical results of the work on the proposed project, contain the planned innovative solution of various bases (sea suspensions on the pontoon and river installed on the bottom at the mouth of the rivers when they fall into the ocean), which determines the image and contributes to the creation of the future product, which in turn is the determining condition for the implementation of the Horizon 2020 Framework project. Similar innovative marine renewable energy technologies and their integration into the energy system of the European Union, call to the Building low-carbon, climate-resilient future based on unique High-performance technologies [8].

The industrial prototype of the hydropower tower an as underwater hydroelectric power plant, including a collector with a protective grid, a generator on permanent magnets, a vortex turbine, a tower, a steering bar with the possibility of turning downstream shown in **Figure 10**.

Initial assumptions for the calculation of the prototype: The consumption in the design of the HPT prototype is taken 2 m/s, and the water consumption is 18,000 kg/s. The diameter of the neck of the tower at Z = 3.5 m - 1400 mm, Z = 5.6-1600 mm, Z = 7.5-1800 mm.

Preliminary laboratory research work of a hydropower tower model showed that there is a correlation between the power emitted by the jet nozzle and the distance to the surface of the water. That is, the lower the underwater power plant is installed, the higher its power should be for the stability of the entire complex.

The main elements of the model of the underwater hydroelectric power plant of the HPP were made of composite materials and painted with water-resistant nitro paint, since the main condition was to test the high corrosion resistance of the station to ensure its long-term use under water.

The HYPOT in the Cartesian coordinate system shown in **Figure 11** is designed to test the principle of operation of the entire system and compare theoretical and experimental results.

5. The subject of the research

The subject of the research is the problem of creating a new technology for the stream generation of high-power products for underwater hydroelectric power plants and hydrogen production services. The subject of the project is topical scientific research (theoretical and experimental), as well as the development of an experimental technical and technological solution for the production of electrical energy in an artificial whirlpool with the possibility of obtaining hydrogen to replenish the peak load of the power plant and use oxygen waste to clean the polluted ocean.

It is planned to apply a fairly simple method of dissociation of water into hydrogen and oxygen and a device for its implementation, suitable for industrial use, which will reduce the energy intensity of the water dissociation process and ensure the possibility of separate production of gases.

To solve the problem and achieve the claimed technical result with a known method of dissociation of water for hydrogen and oxygen, including the effect of an electric field on water or water electrolyte through electrodes located at a distance from each other, and the removal of dissociation products, the effect on water or electrolyte of water by an electric field is carried out with a calculated resonant frequency on harmonics, in relation to which the frequency of natural oscillations of water molecules is multiple. And the dissociation products are removed separately from each even and odd electrode.

Of course, the project will use publicly available data from the experience of construction and operation of all known underwater hydropower projects.

The proposed design of an underwater hydroelectric power plant with a vertical turbine and a hyperbolic housing is very different from conventional wind turbines immersed in water.

Unlike the Orbital Marine Power [4], the "Sea Gen" [9] and another invention [10], HYPOT has a steering stabilizer that easily deploys the structure in the direction of the current, which does not require additional expensive equipment to track the direction of the tidal current, which significantly reduces the construction of an underwater hydroelectric power plant.

The steel structure of the hydroelectric power plant is firmly fixed on the seabed on stilts.

It is necessary to compare the cost of building the most powerful offshore wind turbine and a small HYPOT project. At the same time, the tower can grow as in height, that is, fall lower on a very stable concrete base and without problems scale the power at times. And there is no windmill. This is its limit with the scope of the wind wheel of several hundred meters. At the same time, the weight of the windmill is several tens of times greater.

Oh well, that's why we cover 94% of the solar radiation falling into the ocean and distributed in the currents. And we can bring the power of HYPOT to the required values. And marine windmills have their own limit, depending on the huge size, and perceive only 6% of the solar radiation reflected from the surface of the ocean and distributed in the atmosphere. And do not forget that the density of water is 800 times higher than the density of air, that is, the energy losses in the twigs are simply not comparable to HYPOT.

HYPOT perceives the potential energy of the water hammer, which accumulates as the liquid moves in the collector and almost completely stops it in front of the neck of the tower. When a water hammer occurs in milliseconds, the speed increases according to Bernoulli's law and water gushes into an area of low pressure. Therefore, the process of wave, that is, the incoming kinetic energy is quantized. That is, the process is subject to quantum mechanics, and not just put a windmill in the wind.

HYPOT will completely abandon the construction of dams on rivers. They are no longer needed. Mankind has been using the power of falling water for centuries to obtain electrical energy. Hydroelectric power plants have been operating for decades and affect the climate. Apparently, this is why most people deny a fundamentally new source of energy from water rising up. The conversion of potential energy into kinetic energy occurs into a rollback Gravitational energy is accumulated in water, which is used in soliton therefore the HYPOT has following advantages:

1. First of all, it is the ability to scale HYPOT to the required consumption of electrical energy. Orbital Marine Power (OMP) limited to 2 MW, so to increase power, you need to keep afloat a larger number of boats at anchor. At the same time, they have all the disadvantages of keeping the boat in a stable position on the surface. This complicates operation. HPT has no such limitations.

2. Further, OMP can perceive only strong surface currents and will not be able to perceive bottom currents. In the event of a storm or other phenomena on the surface, strong excitement can immediately stop the operation of the power plant for an indefinite time.

3. OMP in full calm also stops working and can only work in constant tidal currents, that is, in certain places where it is

4. OMP propellers are absolutely not protected from collision with objects passing by it or uncontrolled ships. The areas of operation of such power plant will have to be limited by a barrier given the swing of anchors of several hundreds of meters.

5. HYPOT is hidden under water and on the surface only hatches the nozzle of the tower of a small cross-section. The blades of the vortex turbine are fully protected from environmental impact and the operation of the hydroelectric power plant does not affect the flora and fauna by the noise of the screws.

6. The presence on OPM of service mechanisms for lowering propellers, greatly affects the cost of manufacturing and maintenance, which is deprived of HYPOT.

7. At the same time, it should be noted that the epidural of the distribution of the flow power in the river varies in a large direction from the bottom to the surface, and in the sea - vice versa. This is a physical law and must be followed when designing power plants on the high seas.

In marine conditions, the underwater power plant should operate mainly on the bottom, in the lower reaches, although its design allows it to work in a suspended pontoon state, but in any case, its design should be simple and easily replaceable, which maximizes the profitability of electricity generation and reduces production costs.

6. Development

On the basis of fundamental and applied interdisciplinary research, this project considers the development of methodological, engineering and technological foundations for the creation of a new generation of environmentally friendly and cost-effective technologies and autonomous energy systems based on the use of kinetic and potential energy of bottom and surface currents resulting from changes in temperature and pressure at different depths of the World Ocean and continental rivers.

The project solves the problem of creating efficient energy technologies for autonomous decentralized power supply of offshore oil platforms, including on the Arctic shelf, using new generation underwater power plants and intelligent automated control systems.

The central problem requires consideration and solution of a number of subtasks:

Development of modern computational methods and calculation tools, digital design methods, materials and technologies for the creation of underwater hydroelectric power plants with vertical spiral blades of medium and high power with high hydrodynamic characteristics and structural strength for the conditions of real runoff of bottom and surface waters, as well as climatic conditions inherent in the northern territories.

Analysis, research and development of the theory of intelligent control of the underwater power grid of cyclone HPPs on the example of the use of a primary energy source with a “random” or “stable” nature of the arrival, its reliable forecasting for different time intervals and the development of software and technologies for its effective use.

7. Findings

The development of computers, in particular cluster technologies, allows the use of computational methods of hydrodynamics in the calculation of viscous currents in turbomachines. The introduction of numerical modeling in the process of development and research of the device allows you to reduce the cost of subsequent experimental refinement, and ideally abandon it.

This gives more freedom when solving problems of optimizing the geometry of the blade and other elements, external problems, without resorting to the formulation of the experiment.

To simulate the characteristics and calculation of spiral hydraulic turbines, methods of CFD analysis with large grids comparable in number of cells with calculations of non-sequencer processes, as well as the need for calculations on several low-detectable points to obtain the maximum efficiency mode and increase the energy eclipse of air ducts through four-blade horizontal-axial acceleration using active control systems, new profiles and geo-optimization are proposed blade metrics.

Preliminary results of mathematical tests showed significant results from the possible introduction of such power plants, which can be seen from the attached graph of the dependence of the hydraulic power capacity of the power plant on water consumption.

To study the effect of water hammers on renewable energy, it is proposed to create a pulsed shock wave generator that reproduces shocks close to real ones, and studies their effect on fragments of carbon fiber blades of spiral turbogenerators. Experimental studies of the influence of these effects on the blades are proposed.

As part of the task of digital design of elements and structures of a hydroelectric power plant, it is proposed to develop a design model of a blade system operating in real natural and climatic conditions, conduct CFD analysis using a high-performance cluster and build a 3D model of the blade that has better hydrodynamic performance and less weight compared to analogues.

The solution to the problem of creating a methodology for digital design of the conditions of the Far North (working under the ice) is interdisciplinary and complex: both known proven and tested methods from various branches of science and technology will be thoroughly studied and applied.

Scientifically based technical and technological solutions obtained during the work will be used to improve energy efficiency, efficiency, reliability, safety and technology in the North Sea.

The result of this approach will be the search for solutions for maximum autonomy of power plants without maintenance for a long time, respectively, the proposed systems will be more focused on self-healing, diagnostics and reconfiguration.

Analysis of the problem of building decentralized energy systems based on renewable hydropower sources using the theory of intelligent control.

Analysis and research of modern theoretical and applied issues of calculation, modeling and design of hydro turbine gravitational hydroelectric power plants for their manufacture using a new automated production technology.

Analysis of existing systems of active regulation of fluid flow in marine energy applications.

The analysis of the modern CAD world is adapted for end-to-end digital design of marine gravitational energy sources.

As part of the study of the existing scientific base, a method for forecasting underwater marine and channel river hydropower resources in different time intervals will be developed in order to configure the proposed energy device with the development of an interdepartmental approach to solving project problems.

Notes/acknowledgements/other statements

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Conflict of interest

The authors state that there is no conflict of interest.

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Abbreviations and abbreviations

HYPOT	Hydropower Tower

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