Structural Design Development of a Float Type Wave Micro Power Plant

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Abstract. The purpose of this study was to improve the design construction of a float type wave micro energy converter. Especially we emphasized on the modelling of a metal capsule float type converter in order for better performance of its kind. At the same time we discussed some parameters on the basis of experimental study. Data concerning on the status of wave energetics and the process of development were discussed. The operating principle, advantages of the wave plant and its benefits as compared to the existing technology were reported. The project of a test installation of wave simulator and the research results were presented. The authors also investigated the electro technical characteristics of the generating unit. The developed micro unit of WMPP showed the possibility of energy generation at wave amplitude from 20cm and more when the wave oscillation period $T$ within 1-5sec. The field research with the wave oscillation simulator confirmed the generation values of one micro unit within the capacity limits from 20 to 60W. It will broaden the possible opportunities and increase the WMPP capacity by a certain level if the micro units are constructed in cluster systems.

Keywords: micro generator, wave power unit, wave simulator, cluster system, energy converter

1. Introduction

In Russia the wave energetics stands apart from the various types of renewable energy resources (RER). Meanwhile, in recent times, it arouses a greater interest among the experts of all over the world [1]. The application for a wave power plant patent was introduced in Paris for the first time in 1799. In the year of 1890 the attempt of the practical use of wave energy comes in real for the first time. The first industrial wave power plant with the capacity 850KW had been operating in Norway since 1985 [2]. In the year of 2008 next wave power plant with the capacity 2.25MW was brought into commercial operation 5km offshore in Agucadoura, Portugal. The power plant project belongs to a Scottish company Pelamis Wave Power which in 2005 had concluded a wave power plant building contract with the Portuguese energy producer Enersis. In 2009 wave power plant was brought into operation on Orkney Islands. The installation plan of a new wave power plant with the capacity of 20MW has been taken into account in the United Kingdom [3].
2. Aspects of wave energy efficiency
Wave energy potential depends on the height, width and wave period. Most of the characteristics of wave energy mostly depend on meteorology and geographical location of the surface of heaving. Experts say that in the Northern hemisphere the medium specific capacity of wind waves is about 25 kW/m. In Atlantic Ocean, 1 linear meter of wave surface is capable of producing up to 30000kWh when the wave height is 2.7 m and wave period is 7.1 sec. per 60 h [4]. Regions with the highest specific energy of waves in different parts of the world and regions of the world and seas with the highest specific energy of waves are presented in Table 1 and 2.

| Table 1. Regions with the highest specific energy of waves. |
|-------------------------------------------------------------|
| Region                        | million KWh/ linear meter of wave surface per year |
|-------------------------------|-----------------------------------------------|
| North-West of Ireland         | 0.535                                         |
| South-East of Canada          | 0.465                                         |
| West of France                | 0.420                                         |
| West of USA                   | 0.415                                         |
| Kuril Islands                 | 0.370                                         |

| Table 2. Regions of the world and seas with the highest specific energy of waves. |
|--------------------------------------------------------------------------------|
| Region                      | KWh per linear meter of wave surface |
|----------------------------|--------------------------------------|
| North Atlantic             | 40-80                                |
| India                      | 50-90                                |
| West of Canada             | up to 60                             |
| New Zealand                | up to 35                             |
| Barents Sea                | 22-29                                |
| Norway                     | up to 20                             |
| Sea of Okhotsk             | 12-20                                |

The practicability of wave energy use is determined by its high specific capacity [5]. At sea the specific capacity can be up to 2MW/m for the wave of more than 10m height. Technically, the wave energy can be used only in coastal zones, where the specific capacity does not exceed 80 KW/m. The specific capacity of wind-induced waves in different seas are presented in Table 3 [6].

| Table 3. The specific capacity of wind-induced waves in seas. |
|--------------------------------------------------------------|
| Region            | kW/m                        |
| Caspian sea       | 7-11                        |
| Barents sea       | 22-29                       |
| Baltic sea        | 7-8                         |
| Sea of Okhotsk    | 12-20                       |

Cockerel Raft, Salter’s nodding «duck», oscillating water column, Masuda’s pulsating water column are usually considered as the most common and well known hydro-electrical plant of float type [7]. The best use of wave plants can be very useful for its high level of efficiency coefficient (80%) and possibility of full extraction of wave energy. In the year of 1980 on trial basis Japan installed “oscillating water columns” with quite low level of efficiency coefficient. Several of oscillating water columns were constructed and experimented through the period of 1980s and 1990s in Japan, India, China, Norway, Portugal and Britain. The largest of those built in Japan was the port of Sakata [8]. However the development of wave energy plants of such a type is still continued. The
installations of “Rubber tube” and “Cockerel Raft” type plants are not much profitable at present for its massive construction cost and its low efficiency.

3. Modelling and design basis of a micro power plant (WMPP)

A closed metal capsule wave energy converter of negative buoyancy has been taken into account for construction development. The body frame of WMPP is made of steel rolled tubular products with the diameter of 180mm consisting a spring-loaded pendulum inside.

![Figure 1](image1.png)

**Figure 1.** Unit arrangements of structural settings of WMPP.

A small triple-wound generator has been fixed inside the pendulum case. The cog wheel is located on the input drive of the generator. The cog wheel moves in engagement with a cogged rail, fastened longitudinally inside the wave generator frame. Wave electricity generating unit consists of vertical cylindrical case with a mechanical converter of sea wave energy.

![Figure 2](image2.png)

**Figure 2.** Diagram of wave action on the float micro unit of WMPP.

The rest of it comprises a spring with a plumb, screw pair, clutches, adaptor, idle gear and generator. The construction has embedded speed up gear this is why the rotation to generator is transmitted from the screw pair through the clutches, gear wheels and speed up gear. The clutches are pinion overrunning. A figure of wave motion simulator was presented in the (Fig. 3.).
The unique feature of the cylindrical case of WMPP has two units separated by a baffle—one is accelerating part which includes screw pair and spring with plumb (Fig. 1.) and the other generating part which includes pinion overrunning clutches, adaptor, idle gear, speed up gear and generator [9]. When a wave motion in the upper and lower points appears, the pendulum shuttles and accumulates a potential energy in the spring. When input drive of the generator rotates, the alternating-current is produced. Small rectifier units are provided for creation of a direct-current according to the Larionov’s scheme, making it possible to charge the battery. The diagram of wave action on the float micro unit of WMPP is illustrated in (Fig. 2).

![Figure 3. Simulator of wave-generation for the WMPP.](image)

![Figure 4. Image of WMPP exploratory prototype in the laboratory at the Ural Federal University.](image)

![Figure 5. Capacity measures of WMPP at oscillation amplitude of 0.2 m and period of 1 sec.](image)
Sample of electro technical characteristics of generating unit at direct-current (DC) was shown in (Fig. 5.). The empirical data, with wave simulation of different amplitudes and wave oscillation periods showed that the output power of one unit of WMPP was 15-60W.

Crank mechanism (CM) with a longitudinal mode of terminal segment – traction was used to simulate waves. CM transforms the engine drive rotation in back-and-forth movement of the traction. An induction motor with the capacity $P = 1$ kW and rotation frequency $n_0$ not less than 3000 r/min was selected as a drive. The gearbox was selected on the basis of reduction ratio $Z = 25$. The usage of wave simulation modes with the amplitude $A = 20$, $A = 30$, and the oscillation period $T = 2, 3, 3.5$sec., during the trials, let to receive some necessary technical values and characteristics to estimate the output power and determine optimal and effective operating modes of float type WMPP. The test stand operations were conducted in the laboratory of Eurasian centre renewable energy at the Ural Federal University. The test sample of WMPP was displayed in (Fig. 4).

The capacity of the projected unit can be upgraded to the level of several kW by using several micro units of WMPP combined in one single cluster (Fig. 6). The expansion of future capacity of WMPP to the level of several tens and hundreds kW can be achieved by connecting more micro units in cluster systems of wave micro units (Fig. 7).
4. Conclusion
The developed micro unit of WMPP showed the possibility of energy generation at wave amplitude from 20 cm and more for the wave oscillation period within 1-5 sec. The field research with the wave oscillation simulator confirmed the generation from one micro unit within the capacity limits of 20 to 60 W. Expansion of WMPP capacity to the level of several tens and hundreds kW is possible if the micro units are formed in clusters.

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