ABSTRACT

of the dissertation for the scientific degree of Doctor of Philosophy (PhD) in speciality 6D071800 – "Electric Power Engeneering "

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DEVELOPMENT OF THE DESIGN AND STUDY OF THE PARAMETERS OF AN UNDERWATER WAVE POWER PLANT WITH AN AUTOMATIC CONTROLLED MASS OF THE FLOAT

The dissertation is devoted to the development of the design and study of a new underwater wave power plant created on the basis of a parallel manipulator and having a float with an automatically variable mass.

Relevance. It has been established that surface waves of large water areas (oceans, seas, large lakes) have a huge energy reserve [1,2]. Various wave energy sources are used to extract and use this energy [3]. The theory of wave energy conversion, applied technologies and devices of wave power plant stations (WPPS) have been described, for example, in [4-6] research papers. As the analysis of these works shows, to extract the energy of moving water masses, cylindrical floats are mainly used, and as energy converters, structures in the form of a rod and a cylinder are used. It should be noted that these technologies and technical means do not allow getting a high efficiency because they use energy only for vertical movement of water masses [8]. A number of problems hinder the successful development of wave energy and its widespread use, the most significant of which are the low productivity of WPPS and their predisposition to destruction from wave dynamics and corrosion [7]. These disadvantages make it an urgent task to create an underwater float WPPS with a system for efficient conversion of wave energy into electrical energy, as well as protected from destructive wave dynamics.

It has been known that in most float WPPS, the process of converting wave energy into electrical energy occurs in 2 stages: at the first stage, the wave energy is extracted and converted into the mechanical energy of "organized" motion; at the second stage, the mechanical movement energy is converted into electrical energy. Due to the fact that well-known devices are used for power take-off at the 2nd stage, this thesis paper focuses on the technology and technical means used to extract and convert the energy of water mass movement into electrical energy.

The object of research in this work is a new design of a float wave electric power station.

The goal of this paper– to substantiate and design a new underwater float wave electric power station (FWEPS), create an apparatus for numerical calculations, conduct research and select parameters of a manipulator wave energy Converter. To explore and select parameters of the control system for underwater FWEPS and power take-off and power generation systems.

The idea of the paper is that, based on the experience of using floating marine platforms [9-12], at the first stage, to convert the energy of the float movement into

the movement of six manipulator actuators, use a six-moving SHOLKOR manipulator [13]. Also, the idea is to justify a new ellipsoid shape of the float with an aerodynamic profile in the cross section having two cavities for controlling the mass of the float. A hydrodynamic system for generating electric energy has been proposed. The FWEPS location under water is considered, since this will protect the electric power station from the destructive wave effects. The FWEPS is installed in the coastal zone so that the float is located a short distance below the water surface. Selecting the installation depth provides the necessary amplitude of the float movement. In order to ensure the necessary float position in depth, a mast or frame structure is used that rigidly connects the float and the upper platform of the manipulator.

Scientific novelty:

- A new efficient wave electric power station and technology for converting the energy of a moving water mass (wave) into electrical energy have been proposed, these technologies consist in the fact that the float of a WEPS with an aerodynamic cross-section profile "captures" the kinetic energy of the wave and performs spatial movements that at the first stage are converted by a parallel manipulator into six translational advance of hydraulic actuators; at the second stage, the movement of hydraulic actuators through the hydraulic medium and the hydraulic motor drives a synchronous electric generator;

- A dynamic model of FWEPS has been developed;
- To improve the efficiency of the FWEPS operation, a system for automatic control of float buoyancy is proposed by changing the float mass depending on the wave dynamics;
- A system for generating electric energy based on hydrodynamic forces transmitted by means of fluid from manipulator actuators to hydraulic motors connected to the shaft of an electric machine that generates electric current has been created.

Research problems:

- To get the mathematical apparatus, the scientific and experimental research results, and computer models and programs that will allow creating a design and implement an automatically controlled underwater FWEPS for use in coastal areas as a renewable energy source;
- To create a control system based on automatic changes in the mass of the float depending on the height of the waves;
- To create a hydraulic system for power take-off and generation of electric energy obtained as a result of converting the kinetic energy of the water mass.

Main scientific statements and research results submitted for the defense of research paper:

- The dynamic model of the FWEPS;
- The current demonstration model of the FWEPS;
- Justification of the FWEPS design that effectively uses the full kinetic energy of the water mass movement;
- The computer study results of the float profile;

- The experimental study results to establish the dependence of the increment of the float mass on the wave height;

- The study results and hydrodynamic system calculation for generating electrical current of the FWEPS.

Experimental techniques: To solve these problems, the thesis research used the fundamental provisions of the theoretical foundations of fluid mechanics, the theory of pumped storage electric power stations, and the theory of nonlinear automatic control systems. Some problems have been solved using computer modeling methods using Autodesk Flow Design, MatLab, and MatCad software products. The methods of artificial intelligence Fuzzy Logic Toolbox have been used in Matlab, experimental research methods with the use of information measurement system and Simatic WinCC.

The practical significance of the results obtained is as follows:
A creating a scientific base and tools for creating and implementing a renewable energy facility in the form of an underwater float wave electric power station.

Justification and validity of results and conclusions. Scientific statements, research results and conclusions are confirmed by publishing the main provisions in an international peer-reviewed journal and in journals recommended by the Committee for control in the education and science field, as well as by public discussions at international and National conferences. The efficiency of the proposed technical solution is confirmed by the creation of a working prototype of FWEPS and its testing in an aquarium and a water pool.

The research scope and structure. The thesis research consists of an introduction, the main part of four chapters, and a conclusion. The volume of the thesis research is 107 pages of typewritten text, contains 34 figures, 3 tables, a list of sources used, including 107 titles, 6 appendices.

The content of this research. The introduction substantiates the relevance of renewable energy issues in the Republic of Kazakhstan and beyond.

The purpose and objectives of the thesis research have been formulated, scientific novelty, scientific provisions and research results submitted for defense, practical significance of research results have been determined.

The first Chapter provides an overview and analysis of the state of renewable energy and wave energy, prospects for the wave energy development, wave transformation technology.

The first chapter provides an overview and analysis of the state of renewable energy and wave energy, prospects for the development of wave energy, wave conversion technology. As a result, the tasks of the dissertation were formed. In the third Chapter, a dynamic model of a float wave electric power station with a manipulator Converter is developed. In this chapter it is indicated that a more efficient transformation of wave energy should consist in extracting the energy of six motions of water particles. The fabricated working demonstration model of PVPS is described. The results of tests in an aquarium and on a natural reservoir with a small wave are

given, which confirmed the functionality of the VLES and that it generates electrical energy by extracting the energy of water movement. This chapter summarizes the advantages of the new PVPP, which are as follows: firstly, the technology of converting all spatial movements of the float into organized translational movements of six actuators can increase the productivity of the VLES six times; secondly, the hydraulic power take-off system allows converting the movements of all six actuators into the rotational movement of the generator shaft; thirdly, the use of a two-cavity float makes it possible to control the mass of the float depending on the dynamics of the waves; fourthly, the location of the float under water protects the PVLES from the destructive effects of waves, increasing its service life;

In the third chapter, a dynamic model of a float wave power plant with a manipulator transducer is developed. In this chapter, a mathematical apparatus has been obtained that allows to numerically determine and select the design parameters of the VLES, ensuring its efficient operation. Also, an algorithm has been drawn up for calculating the speeds of movement of the actuators and the forces acting on the actuators.

In the fourth chapter, a study and selection of parameters of the control system and generation of electrical energy of the VLES was carried out. In this chapter, it is proposed to apply the method of controlling the change in the mass of a two-cavity float to control the power of energy conversion of the water mass. An expression for the control action aimed at automatic change in the mass of the float, depending on the wave height, is obtained experimentally. An information-measuring system and a functional diagram of the automation system for controlling the PVLES and the mass of the float were also formed. Energy calculations were carried out to confirm the possibility of practical implementation of the PVLES design. Based on the analysis of electrical machines, a synchronous machine with an inverter and an intermediate circuit was selected. A functional diagram of the controlled generation system of the PWLES has been formed.

The research results are given in the conclusion.

- The substantiation and design of a new underwater float wave power plant is given, the operation of which is based on a new technology for converting wave energy into electrical energy.
- A working model of PVlES has been created and tests have been carried out to confirm its functionality.
- An apparatus for numerical calculations of the design parameters of the VLES using a computer has been created.
-The parameters of the primary manipulator wave energy converter were investigated and selected.
- To ensure the effective functioning of the PVPS regardless of the dynamics of waves, a float design is proposed that allows controlling the mass of the float.
- The structure and parameters of the automated control system for the float and underwater PVPS have been investigated and selected.
- Hydrodynamic power take-off system was selected.
- A controlled system for generating electrical energy for the underwater PVPS was created.

Scope. The field of application is power supply with the help of a wave power plant for the population living in coastal areas of large water areas. PVlES can be used for power supply of floating oil and gas production platforms.

The external doctoral candidate's personal contribution consists of: the problems posed in the dissertation using the fundamental provisions of the theoretical foundations of fluid mechanics, the theory of pumped storage power plants, the theory of nonlinear automatic control systems. Creation of a demonstration sample and conducting experimental research. When solving a number of problems, methods of computer modeling were used with the use of various software products.

Approbation of the thesis research results and publications. The main provisions of the thesis research have been reported, discussed and approved:
- at scientific and technical seminars of KSTU;
- at 11 international conferences, including 1 foreign.

Also, the main provisions of the dissertation are contained in the following publications of the author:

1. K.S.Sholanov, Zh.R.Issayeva. Волномерные буи в ряду современной энергетики А4 // Scientific tr. International scientific-practical conference "Integration of science, education and production - the basis for the implementation of the Plan of the nation" (Saginov readings No. 10). - Karaganda: KSTU, 2018 – Ч. 2 – С. 246-248
2. Zh.R.Issayeva, A.Bakitzhankizi. Определение плавучести поплавка по программе COMtoCSV //Scientific tr. X international scientific and practical conference "Competitiveness of the nation - the main condition for improving the well-being of the people" dedicated to the 55th anniversary of the Karaganda State Industrial University. - Temirtau: KGIU, 2018 – Ч.2 – С.45-46
3. Zh.R.Issayeva, A.Bakitzhankizi. Геометрические характеристики первичного манипуляторного преобразователя //Scientific tr. International scientific-practical conference "Integration of science, education and production - the basis for the implementation of the Plan of the nation" (Saginov readings No. 10). - Karaganda: KSTU, 2019 – Т. 3 – С. 48-50
4. K.S.Sholanov, Zh.R.Issayeva. Применение параллельного манипулятора SHOLKOR в качестве преобразователя энергии ВЭС//VIIscientific-practical conference with international participation "Science of the present and the future" Saint Petersburg State Electrotechnical University "LETI" Ulyanov V.I. (Lenin) .- St. Petersburg, RF: 2019 – Т.1 – С.213-2015
5. K.S.Sholanov, Zh.R.Issayeva. Формирование динамической модели подводной ПВЭЛС// VII Global Science and Integration 2019 "Central Asia International Scientific and Practical Journal." Nur-Sultan:2019 – Т.4 –С.225
6. K.S.Sholanov, Zh.R.Issayeva. Обоснование конструкции новой поплавковой волновой электростанции // Научно-технический журнал «Автоматика. Информатика» - Караганда: КарГТУ, 2019. – №2[45], - С.8-11.
7.K.S.Sholanov, Zh.R.Issayeva. Управляемая поплавковая волновая электростанция // Bulletin of PSU named after S. Toraigyrov. Pavlodar: 2019 –В.№4 – С.195-207

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