Analysis and Classification of Low Head Hydro Power Based on Advanced Morphological Approach

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Abstract. The paper discusses hydrokinetic systems low head hydro power as an element of renewable resource. In the paper a review of the existing and upcoming orthogonal and axial turbines schemes is outlined. Based on a morphological approach comprehensive survey of various schemes and qualitative comparison, is presented. The proposed engineering solutions reduce the structure weight and the processability increases. These factors lead to a decrease in the cost. The engineering solutions under consideration are designed to operate in low-pressure flows, regardless of their direction. Thanks to these features, the scope of their use expands. They can be used both in high tide and in the use of the sea currents kinetic energy.

1. Introduction

Currently, there is a constant search for alternative energy sources. The goal is to produce energy with low cost and high technology and scalability. At the same time, energy must be environmentally friendly [1-4]. Efficiency and optimization of engineering systems play a significant role [5,6].

Water power is a significant source of renewable energy, where the waters represent 70% of the earth's surface and considered as an enormous source of energy in the form of wave, tidal and marine current [7,8]. Water energy is a kind of hydro energy. Water energy, an embryonic energy solution, has enormous potential for energy production in future. Water energy technologies are relatively new and applications are developing at very fast pace [8].

Recently, there has been a growing interest in the synthesis of Low Head Hydro Power (LHHP). Existing low-pressure tidal power plants use axial turbines. When these turbines work, the flow of water moves along the turbine axis. In tidal power plants, the basin is completely insulated from the sea.

The alternative to axial turbines is orthogonal turbines located under water. The rotation axis of the orthogonal turbine is perpendicular to the direction of the water flow. The Engineering Solutions (ES) will reduce the weight of the structure with a simultaneous increase in technology. These factors lead to lower costs. The ESs under consideration can operate at low pressure flows regardless of their direction. Consequently, they do not require insulation and can be installed on the high seas. The scope of their use is also expanding. They can be used both in the tide and in the use of kinetic energy of sea currents.

Analysis of the descriptions of the LHHP inventions allowed us to identify five main areas of improvement of low-pressure power plants [9]:

1. increase of work efficiency-efficiency factor;
2. improving the design of installations-reducing the size;
3. expansion of functional and operational capabilities;
4. improving the reliability;
5. the reduction of the cost.

The contribution of the main areas of improvement is shown in Figure 1.

![Figure 1. Share of different areas of improvement low-pressure tidal power plants.](image)

From the above data, it follows that the most promising direction is related to increasing efficiency, design and operational excellence

2. **State of the art**
Vertical axis turbines use tidal flow from any direction. This allows you to receive energy in two directions, the incoming and outgoing tide. In such turbines, the rotation speed is low. There are several basic types of devices and turbines with a vertical axis (fig.2) [10-13]. For example, a Kobold turbine (fig.3) or Gorlov turbines (fig.4) [10,12].

![Figure 2. Vertical-axis turbine arrangements [10].](image)
3. Analysis and classification based on morphological approach

3.1. Morphological matrix creation

The main difficulty during the search for the design of an ES is the uncertainty of the results due to incomplete information on evaluation criteria [14]. The most common method among the discursive techniques is the morphological analysis [15]. Whereas morphological analysis is a method (developed by F. Zwicky) to explore all possible solutions of a multi-dimensional, non-quantified problem complex
Zwicky applied this method to such diverse tasks as the classification of astrophysical objects and the development of jet and rocket propulsion systems. More recently, morphological analysis has been extended and applied by a number of researchers in the USA and Europe in the field of future studies, engineering system analysis and strategy modeling [15]. Today, the morphological approach serves as a standard when new systems are being designed. At present, there are many methods to search and synthesize solutions based on the morphological analysis in a variety of physical and engineering areas [15].

The advanced morphological approach is based on the author's works [16-18]. It allows you to effectively reduce the number of variants considered and choose the best ones. A software “Okkam” was created to implement the approach. The software allows you to build a morphological matrix and criteria tables. In the future, generation, clustering and selection of options are carried out [19].

The process begins with the construction of criteria table (Table 1) and morphological matrix [9].

**Table 1.** Criteria table for LHHP design schemes

| Criteria            | Weight coefficient |
|---------------------|--------------------|
| 1 Weight            | 0.15               |
| 2 Cost              | 0.2                |
| 3 Reliability       | 0.2                |
| 4 Efficiency Electricity | 0.25          |
| 5 Exploitation (simplicity) | 0.15          |
| 6 Ecology           | 0.05               |

**Table 2.** Morphological Matrix with Possible Engineering Solutions.

| Attributes               | Option 1        | Option 2             | Option 3                  |
|--------------------------|-----------------|----------------------|---------------------------|
| The location of the turbine | Orthogonal    | Axial                | Multiplier + Inverter     |
| Generator type           | Linear generator (inductor) | Axial generator   |                          |
| Energy conversion        | Multiplier      | Inverter             | Hexapod girders           |
| Spatial design           | Console mounting blades in the tier | Two-way (rings, plates) | Hexapod girders           |
| Pinning the ground       | Pillar          | Bars                 | Hexapod girders           |
| Construction of turbine tiers | Flat guides | Persistent hydrodynamic bearings | Hydrostatic bearings |
| Getting hydrogen         | Water electrolysis | Extract from activated Al |                          |
When considering the systems as a whole, the assessment was carried out taking into account the criterion of efficient use of electricity. As a result of the analysis of patent solutions, a matrix was compiled (Table 2) with the power of the morphological set - 3888 variants.

In the future, the options were generated, evaluated, and selected for a certain set. The best engineering solutions received the highest scores based on expert assessments. This procedure made it possible to significantly reduce the number of options under consideration and leave a small part for further analysis.

3.2. Structural synthesis

To analyze the possible design of LHHP, the first six attributes were selected, a ballroom assessment of the features of the signs for each criterion was carried out, 68 variants (54 selected, 7 supporting and 7 converged) were selected, and the tr classification fields (Figure 5-6) were constructed [9].

According to the studied ESs of LHHP, the following research areas are recommended:
- engineering solutions - low-pressure LHHP - increasing efficiency, reliability, reducing cost and weight;
- engineering solutions for special hydrodynamic bearings for tidal turbines operating on seawater — measures to reduce the coefficient of friction and increase reliability;
- engineering solutions of a multi-blade turbine, the rings of which are connected in each tier in the form of a spatial truss-reducing cost and weight, increasing rigidity;
- engineering solutions of multipliers for tidal stations with the purpose of using standard electric generators in them-reduction of cost and weight;
- engineering solutions production of hydrogen and heat-electrolyzers-increase in efficiency and reliability of operation, increase in manufacturability;
- engineering solutions—hydrogen storage-weight reduction, increased ease of maintenance.

When analyzing the selected ESs with higher characteristics were proposed [9]. For example, instead of the basic scheme of an orthogonal two-tier turbine (Fig. 7) with two generators and multipliers, it is advisable, according to the criteria of cost and reliability, to apply the transmission and use one generator and multiplier (Fig. 8).

![Figure 7. The version with one multiplier and generator.](image1)

![Figure 8. The basic version of an orthogonal turbine.](image2)

4. Conclusion
The paper presents a brief overview of the existing and promising turbines schemes. The research was conducted in order to increase the probability of creating workable LHHP with high performance and reduce the risk of technological nature. Analysis of trends in the development of research and development based on the morphological approach made it possible to select the most promising areas of research.

The proposed algorithm made it possible to generate variants, evaluate and select a certain set. The assessment was carried out with the help of experts. The proposed solutions will reduce the weight of the structure while increasing the processability and reducing the cost.

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