IOP Conference Series: Materials Science and Engineering

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To cite this article: M Yu Shabalov *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **643** 012143

IOP Conf. Series: Materials Science and Engineering **643** (2019) 012143 doi:10.1088/1757-899X/643/1/012143

Prospects of binary energy generation systems based on the joint use of traditional sources of energy and wave motion energy

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Abstract. Electricity consumption of offshore oil and gas drilling platforms is usually provided by gas generator installations. However, such installations are expensive in operation and emit significant amounts of carbon dioxide and nitrogen oxides. Electricity consumption from the main grid is the best option, but expensive for platforms located far from the coast and with limited environmental benefits, if not supported by environmentally friendly production. Offshore wave energy technology, which is currently being developed for deep-water areas, can be connected directly to the platforms and work in parallel with gas turbines. Wave power station will save fuel and reduce carbon dioxide emissions, while there is no need for a long and expensive connection to the coastal grids. Operational strategies and fuel savings and emissions, depending on the size of the wind farm, are quantified by the example of the offshore oil and gas platform in the Far East shelf. In this paper, an assessment is made of the prospects of using the approach of dual power generation systems, which in turn will provide a significant reduction in fuel consumption and emissions, especially if we consider starting and stopping gas turbines. The main task is to find the optimal work strategy that balances the number of starts and stops of gas turbines with dissipative energy and fuel economy.

Introduction

Over the past twenty years, such a component of the energy industry as renewable energy sources (RES), has gone from experimental development to being one of the major parts of the energy balance of some regions and even countries (in Germany - 26% of electricity production in 2016 and 30% in 2017; in China - 5.9% and 7.2%, respectively [1-4]) and turned into one of the most promising areas for the transformation of existing energy markets. With the help of the energy generated from the air in the direct and figurative sense, many countries are trying to diversify the energy balance, that is, there is a failure or replacement of a certain proportion of the traditional energy sources purchased. In addition to the economic and strategic effect, there is an environmental one, manifested by the reduction of harmful emissions into the atmosphere with an overall increase in the safety of electricity production. For some developing countries of the world, this effect comes to the first place in importance due to the existing problems in this area (for example, permanent smog in Beijing, the risks of atomic energy in Germany).

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One of the features of RES is the variety of ways in which a person transforms one and the same energy of the sun in its various manifestations into more convenient forms for itself [5-6]. There are several types of renewable energy sources, which differ greatly in the cost of energy produced and in energy efficiency - EROEI. Energy profitability is one of the most theoretically objective characteristics for evaluating projects in the energy industry, since it evaluates them most rationally, since in this study an important aspect is the distribution between the energy spent and the energy received. From the point of view of EROEI, RES can be defined as “sources with sustained energy profitability,” unlike non-renewable sources, such as oil, whose figures dropped from 100 in the 1930s to 10–20 in the modern world: on the shelf and in super heavy conditions[7].

Wave power, its features and characteristics

The first practical appearance of a 1 kW power plant, which converts wave energy into technical devices, was recorded in the period 1900–1930 Currently, patent offices register several dozen original wave converters annually, starting with the period after the oil crisis. The main advantage: the amount of energy that can be obtained from the ocean waves is enormous, while the conversion percentage is quite high, since the wave energy is concentrated wind energy, and, ultimately, the sun. Compared with the energy of wind and sun, the wave energy, given the surface area occupied by water resources, has a much higher specific power (the power of the world's oceans is estimated at about 2,700 GW). However, there remains the problem of efficiently converting this energy.

The power of the oscillatory motion of the waves is estimated in kW / m. The energy per unit length of a wave front in deep water (when the bottom does not affect its shape) is proportional to the square of the amplitude and the wave period:

$$\omega = \frac{\rho \cdot \alpha^2 g^2 T^2}{4t\pi} \tag{1}$$

where ω is the wave energy per unit length of the wave front, kW / m; ρ is the density of the fluid in the wave, kg / m^3; α - wave amplitude, *m*; g — gravitational acceleration, m / s^2; T is the wave period, s; t is the total oscillation time.

Thus, the average power of the seas and oceans waves, as a rule, exceeds 15 kW / m. With a wave height of 2 m, power reaches 80 kW / m. In Russia, it is possible to master the energy of sea waves on the coast of the Pacific seas, as well as the Barents and Black seas.

Description of the study

Taking into account the prospects of this trend, the authors developed a new scheme for the wave power plant (WPP) (Figure 1), which is characterized by simplicity of the device and the insignificance of wear of the working parts of the mechanisms [6].

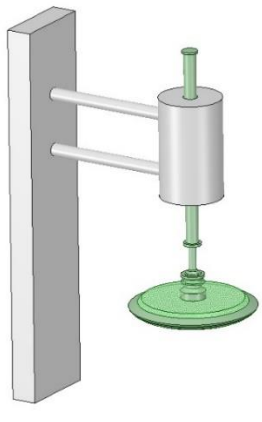

Figure 1. Wave power plant.

Wave power plant contains (Figure 1) a vertical rack, which is installed in the sea soil or on any available support. In the fortified case there is a linear electric current generator, which consists of a stator and an inductor capable of vertical reciprocating motion. The hollow box protects the linear current generator from moisture (rain, splashing waves), and the non-metallic body is not subject to corrosion. This solution has significantly simplified the entire structure in comparison with the existing analogues. In addition, this device proposed design of the magnetic circuit, which consists of two main parts. The outer part is made in the form of a package of round plates with four poles, and the inner part is a similar set of plates placed on the inner side of the inductor. The movable inductor consists of a frame made of a non-magnetic material and eight magnets placed on it. The winding in the form of lumped coils is placed at the poles of the magnetic circuit, while the magnetic flux created by the permanent magnets is summed and passes through the poles of the magnetic circuit, changing its direction depending on the position of the moving part (inductor).

The optimal solution is to use a linear generator with permanent magnets, this type of generator meets the necessary requirements of reliability and durability of the structure in extreme operating conditions. The use of high-energy permanent magnets in linear generators makes it possible to reduce the mass of the installation and makes it possible to obtain a non-contact type electric power generator. Recently, a considerable number of constructive solutions have been proposed on the subject of linear generators, mathematical models have been developed, and design issues have been considered.

Like any other wave transducers, the installation does not harm the environment and under certain conditions can operate continuously. This type of wave installation provides increased efficiency in comparison with analogues, reliability of operation, increase in service life while simplifying the design (when the movement of the stator, and not the rotor occurs). The linear generator of electricity allows us to avoid many of the problems of wind energy associated with numerous engine failures and increased wear of parts. An important characteristic of the proposed installation is the absence of unique details, since the design does not require light alloys, as for the blades of wind turbines, nor expensive photovoltaic solar panel elements. The combination of these factors should lead to a high EROEI due to lower Energy Invested component, as well as to relatively low prices for the disposal of each unit. According to the site: oilprice.com, during the period of enthusiasm for "green" energy in Germany, about 25,000 wind turbines were installed, and 7,000 of them are approaching replacement. In this case, the utilization of one turbine at a cost reaches 33.5 thousand euros due to the cost of special equipment and labour costs.

The power supply diagram of the oil platform in the case of using dual systems [7], is shown in Figure 2.

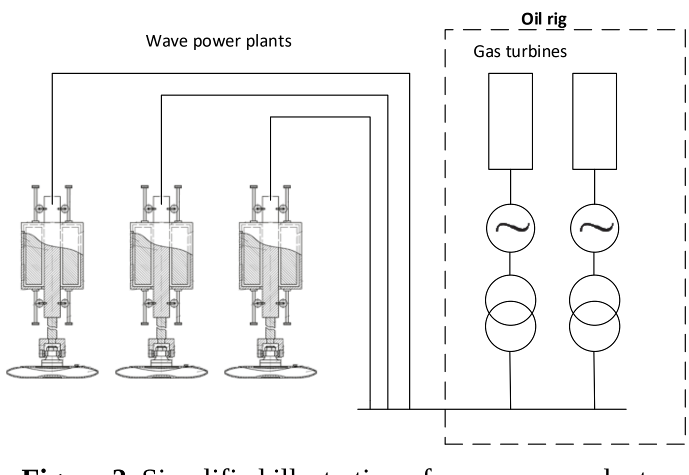

Figure 2. Simplified illustration of wave power plants.

Currently, the need for electricity for the oil platform in the case under consideration is provided by two gas turbines, and the third turbine is a backup. Under normal operating conditions, gas turbines distribute the load equally. Gas turbines are of the same type with a power of 23 MW and fuel characteristics, as shown in Figure 3.

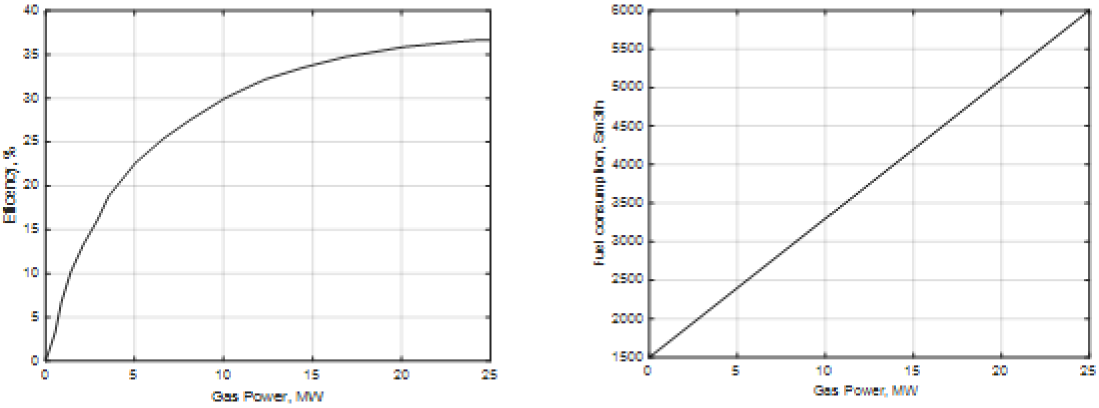

Figure 3. Efficiency curve (Higher Heating Value) and fuel consumption curve for the gas turbines.

As seen in Figure 3, the fuel efficiency drops sharply at low loads, and the fuel consumption at idle is about 20% of fuel consumption at full load. power. The power consumption during the year usually ranges from 20 MW to 35 MW, is quite constant, but can quickly change due to different starts and stops of the engine.

3.1. Evaluation of the effectiveness of binary systems

Wave movements and wind conditions near the oil platforms of the Far Eastern shelf are often very favorable, with an average wave height of about 2 m and a wind speed in the range of 10-11 m / s [8]. Wave power plants can be located near the oil rig and operate in parallel with gas turbines. If the power of the motion of the waves is low compared to the need for electricity, fuel economy and emissions will be proportional to the output power of these plants.

To estimate the approximate direct effect of installing a dual system on an oil platform, we use data from Norwegian researchers [8-10], who say that on an average platform in the North Sea about two gas generators with a capacity of 23 MW are used, since the load on the platform varies from 20 to 35 MW. The average load also accounts for the average amount of emissions of carbon dioxide and nitrous oxide, the fee for which is determined by law. It is exactly the savings on flared gas and emissions into the atmosphere that are considered as the main economic effect, which, in the framework of the aforementioned study, ranges from 4.23 to 5.73 million euros for a 20 MW wind generator. The difference of 1.5 million is due to differences in the proposed schemes for the inclusion of generators.

To assess the alleged indirect effects of the installation of a dual system, we determine the risks of individual projects that will result in savings as a result of using dual power supply systems. Since the occurrence of risks in an investment project varies greatly depending on the techniques and technology used, it is important to consider them within the time factor. The combination of the risk assessment procedure with the time scale on the example of projects in the energy sector is clearly presented in Figure 4. A more rigorous quantitative justification for the use of this scheme in the analysis of specific options for an investment project can be extremely useful for investors.

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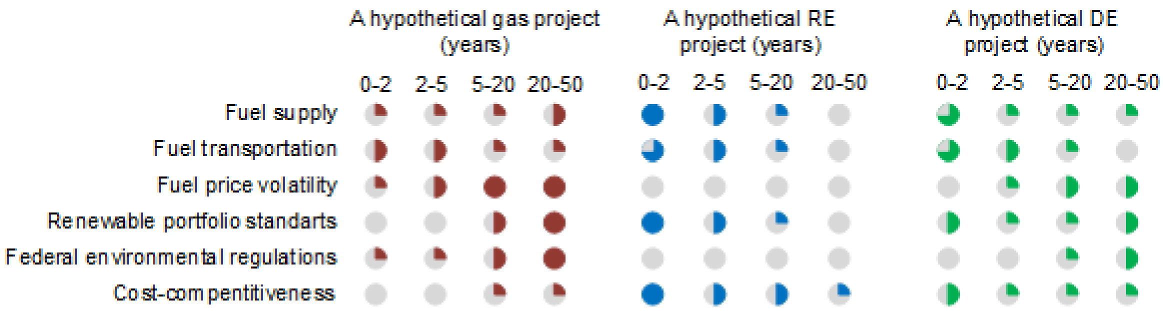

Figure 4. Comparison of risks of different types of energy projects over time.

For the development of dual projects, the following general ideas were used:

- Continued improvement of renewable energy technologies and related methods of power transmission;
- Reduction of the amount of available hydrocarbon raw materials and a drop in its energy profitability;
- Adherence of any state to its energy interests and respect for energy security.

The result was a risk assessment of a dual project over time (Figure 4): it is obvious that the indirect effect of the use of dual projects is a significant reduction in the risks of investment processes. Thus, the use of dual renewable energy systems and traditional sources can bring a very significant effect, regardless of the type of renewable energy sources, but taking into account their power characteristics.

Conclusions

The research potential of developmental and economic valuation of renewable energy is enormous. First of all, this is due to the innovative orientation of projects in this industry, the lack of a basis for comparing the results, and commercial secrets of modern projects on this subject. Particularly acute is the question of obtaining funding for the creation of the first prototypes for new technologies. The only reliable source of information on costs in this industry is its own experience, since all other sources of information either show interest in a positive coverage of the issue, or, conversely, in a negative one. Thus, according to the authors, when assessing investment projects in the renewable energy industry, the most appropriate way is the income approach in the first stages before the creation of a prototype and the cost approach after the development work (R & D). At the same time, in order to reduce the cost of research, it is necessary to deal simultaneously with R & D issues and the evaluation of the income approach to certain installations.

The use of dual power generation systems can have significant economic and environmental effects. As a renewable energy source, the wave installation offered by the authors combined with traditional energy sources can be used. The results of their work can be both heat and electricity, depending on the consumer. If such dual systems will have increased stability, then we can talk about solving the “peak” problem, which is strongly associated with renewable energy. This prospect against the background of the annual increase in their share in the energy market suggests the study of such systems in the future.

The environmental effect of dual systems, which can be used instead of traditional ones, should be assessed separately, but already now there are attempts to evaluate it for the most common renewable energy sources. Unfortunately, their energy profitability requires additional justification, which can lead to an incorrect assessment of dual systems. Further directions of this study are the creation of a prototype from the technical side and the creation of a detailed description of the method for calculating the EROEI indicator, taking into account its classifications for RES.

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