Торайғыров университетінің хабаршысы
ҒЫЛЫМИ ЖУРНАЛЫ

НАУЧНЫЙ ЖУРНАЛ
Вестник Торайгыров университета

Торайғыров университетінің ХАБАРШЫСЫ

Энергетикалық сериясы
1997 жылдан бастап шығады

ВЕСТНИК Торайгыров университета

Энергетическая серия
Издается с 1997 года

ISSN 2710-3420

№ 2 (2023)

Павлодар

НАУЧНЫЙ ЖУРНАЛ
Вестник Торайгыров университета

Энергетическая серия
выходит 4 раза в год

СВИДЕТЕЛЬСТВО
о постановке на переучет периодического печатного издания,
информационного агентства и сетевого издания
№ 14310-Ж
выдано
Министерство информации и общественного развития
Республики Казахстан

Тематическая направленность
публикация материалов в области электроэнергетики, электротехнологии, автоматизации, автоматизированных и информационных систем, электромеханики и теплоэнергетики

Подписной индекс – 76136

https://doi.org/10.48081/ABAC7746

SRSTI 44.37.29

https://doi.org/10.48081/RGMZ4495

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ALTERNATIVE TECHNOLOGIES FOR AUTONOMOUS POWER SUPPLY

The article considers the relevance of the use of autonomous power systems powered by renewable energy sources for use in the agricultural sector in the conditions of the Kostanay region. The main features of energy supply systems from the point of view of the rationality of their construction with a low population density and developed agriculture are considered. The share of the component in the structure of the cost price and tariffs for electricity associated with the generation of electric power is given. The share of electric energy costs in the production of agricultural products is determined and ways to reduce them are outlined. The possibility of using hybrid autonomous power plants for water supply for agricultural needs is considered. The article presents the device and the principle of operation of alternative technologies for obtaining thermal, mechanical and electrical energy using a solar water jet and a greenhouse generator. A comparative analysis of the advantages and disadvantages of the considered alternative technologies is carried out, on the basis of which design changes and improvements to existing structures are proposed. It is proposed to use a Stirling engine to generate mechanical energy in conjunction with a greenhouse generator, allowing the wind generator to generate electrical energy. The main advantages and versatility of the hybrid design, in comparison with the original ones, allowing the use of renewable energy, are noted.

Keywords: energy of sun; wind energy; heliojet; greenhouse generator; power supply systems.

Introduction

Prospects of the use of renewable energy sources is dictated by the diversification of energy sources, energy security of the country, the use of the requirements of international agreements in the field of ecology, the development of new technologies in the field of energy supply and energy efficiency characterizing the relevance of developed ideas [1, 2].

The strategic potential for the use of renewable energy resources in the world is huge. According to experts, they are many times higher than the most optimistic estimates of traditional hydrocarbon fuels, which make the prospect of their use very attractive [3,4]. The share of renewable energy usage in the world continues to grow every year. The feasibility and scale of the use of renewable energy sources are determined primarily by their economic efficiency and competitiveness with traditional energy technologies [5,6].

Renewable energy has a number of advantages over traditional energy sources:

- independence from traditional energy related to the use of fossil fuels, in conditions of its limited and uneven distribution among countries;
- independence from price volatility in the global fossil energy market;
- inexhaustibility of renewable energy sources;
- eco-friendly use in the absence of waste and the release of pollutants;
- adaptability to the usage [7].

One of the priorities for the development of the electric power industry and the solution of environmental problems in Kazakhstan is the use of renewable energy resources. According to expert estimates, the potential of renewable energy resources (hydropower, wind and solar energy) in Kazakhstan is very significant. The share of renewable energy sources in the total volume of electricity production in the Republic is 0.5 % [8].

The following types of renewable energy sources are most promising for the territory of Kostanay region: wind power; small hydroelectric power plants; solar installations for the production of heat and electricity. Near Tobyl town the construction of the Ybray wind power station is going on, the first stage of which is already in operation.

Since the area is dominated by agriculture, the use of biomass energy is obvious. Also, we should not forget about the use of solid household waste and wastewater for energy production, solving the problem of waste accumulation and energy production at the same time [9].

Materials and methods

A characteristic feature of Kostanay region is a relatively low population density and developed agriculture. In this regard, it is important to use autonomous power plants from renewable energy, which allow you to provide electricity and heat to stand-alone social facilities, residential buildings and production facilities [10].

This article is devoted to the use of alternative technologies for processing renewable energy in autonomous power plants to provide water supply, mechanical, thermal and electrical energy to consumers [11].

The tasks that make it possible to achieve this goal are:

- consider existing alternative technologies for generating energy from renewable sources, their advantages and disadvantages;
- improve the efficiency of autonomous systems.

To achieve this goal, various scientific methods were used, such as the analysis of the literature on the problem under study, generalization, comparison and systematization of theoretical and empirical data.

As it is known, the main disadvantage of renewable energy is the frequency of energy flows. Solar energy can be consumed in the daytime, while wind energy in nature exists regardless of the time of day. If we consider the potential energy flows by season, we can note the following, that the potential of solar energy prevails in the summer, and wind energy in the winter. Thus, the combination of different types of renewable energy in a single system eliminates the problem of instability of energy flows. Autonomous stations combine several different energy sources that complement each other and stabilize energy flows. Renewable energy extraction technologies are diverse and have a number of specific features [12].

It is known that in the process of extraction, production, transportation, storage, consumption of organic energy resources (fuels), at all the listed successive stages of the promotion of energy from primary sources and at all stages of energy use in material production and the service sector as a whole, about 90 % of energy is lost compared to the initial level [13,14].

In the structure of the cost price and electricity tariffs 27 % is generated by basic power plants. The rest of the components are related to transportation, distribution, and energy losses. Therefore, the power supply of remote settlements from centralized systems is not economically profitable, since it requires large capital investments for the construction of power transmission lines and transformer substations. At the same time, the share of electric energy costs associated with the processing and production of agricultural products is 34 %. Thus, the use of autonomous power plants is economically feasible [15].

One of the ways to solve the problem of consumption and production is to generate the necessary types of energy in remote areas through the use of renewable energy sources directly near the consumer.

In electronic publications, numerous systems and installations of renewable energy are widely presented under various names, each of them has its own advantages and disadvantages, depending on the geographical location of the energy consumer, the operating mode, and the temporary needs for certain types of energy. In addition to traditional methods of energy utilization of renewable resources, alternative technologies for using the heat of solar radiation are being developed [16–19].

Taking into account the specifics of agriculture, watering and irrigation during the growing season of crops, water for livestock, it should be noted that almost 80 % of the cost of water supply is electric energy. Russian scientists have proposed the use of solar water jets for these purposes. To solve the problem of reliable and inexpensive water supply, solar energy can be used; after all, for irrigation, for example, fields need an average of about 0.5 kW of installed capacity per 1 ha (0.05 MW/km^2) [13].

The solar water jet is powered by a solar concentrator and solar heat stored by a salt pond. The heat from the pond is fed through a heat pipe (thermosiphon) to the water jet, which is a Stirling engine with a water pump, where it is converted into the energy of the water flow (liquid) in the thermodynamic cycle. The heat not used in the thermodynamic cycle of the water jet is diverted through the heat pipe: either through the cooled part of it into the pit filled with ice, causing it to melt, or it is dispersed into the environment through its air-cooled part. Thermosyphons are vacuum tubes in which heat is transferred by boiling the working fluid (for example, water) in one place (lower) and condensing in another – upper (Figure 1).

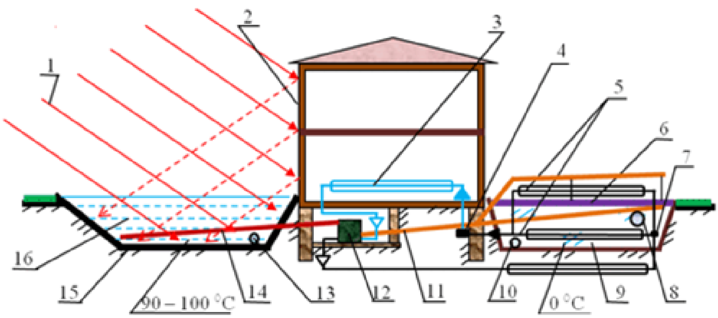

Figure 1 – Design of the solar water jet
1 – solar radiation; 2 – solar radiation concentrator; 3 – thermal insulation coating; 4 – pit filled with ice; 5, 8 – thermal gravity pipe (thermosiphon); 6 – air duct; 7 – water jet (Stirling engine with water pump); 9 – solar salt pond; 10 – water supply; 11 – ground; 12 – cooled part of the thermal gravity pipe 5, placed in the air – the perimeter fence of pit 4; 13 – cooled part of the heat pipe 5, located in the ice/water of pit 4

The disadvantage of such a device is the large area and volume of the pond and the pit with ice, the presence of a large solar energy concentrator. For efficient operation of the solar water jet, an automatic process control system and the use of excess heat energy are preferred.

The idea of using the energy of an artificial tornado-like flow excited by the wind, running into a tower with blinds that opened from different sides in relation to the direction of the wind flow, was developed in the works of D. Yen. In one of the modifications of the models of the greenhouse power plant of the Canadian meteorologist Michaud, the possibility of forming an artificial wind by fire tornado-like vortices of the «dust devils» type was envisaged. It was proposed to enclose the tornado - vortex created by heating the underlying surface of the collector in a low tower, in which periodic impacts on the lower part of the swirling flow are organized. According to the author, to obtain large values of electrical power with the help of a tornado, there is no need to create a high pipe [20].

Results and discussion

In this regard, we can consider the process of converting thermal energy in solar wind generators, which create air flows initiated by solar heating of the air environment in semi-closed «greenhouse» systems. Designs of power plants have been developed that allow concentrating the energy of direct and scattered solar radiation, converting it into the energy of air flows with subsequent generation of electrical energy. Such constructions are based on the proposed I. Cabanes model of a greenhouse power plant, which he called a solar engine, (Figure 2) actually used the principle of operation of a chimney.

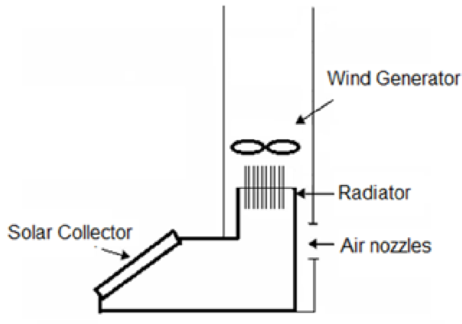

Figure 2 – Model of a greenhouse generator

The main disadvantages of this model are the low efficiency and large dimensions. Calculations of the efficiency of the model performed in the approximation of the ideal Carnot cycle and therefore led to relatively low values of the efficiency coefficient. Meanwhile, it is necessary to pay attention to a number of fundamental design features of the solar engine model, which were lost later in the development of technologies for the aeromechanical method of converting solar energy and allowing us to clarify the real thermodynamic cycle. These are the unsymmetrical configuration of the solar collector, its tightness along the circular periphery, and the flow of air into the chamber through a limited-sized and flow-controlled inlet, similar to a furnace air-charging device that increases the draft in the chimney. An analysis of the design features of the solar water jet and the greenhouse generator suggests that by combining these devices into one system, it is possible to partially eliminate the shortcomings of each separately and increase the efficiency of solar energy conversion.

The hybrid model is based on a greenhouse generator, in which the energy of the sun is converted into thermal energy by means of a solar collector. The thermal energy is converted into mechanical energy with the help of the Stirling engine and drives the water pump in action. A wind generator is installed in the upper part of the pipe, which converts the energy of the wind flow into electrical energy (Figure 3).

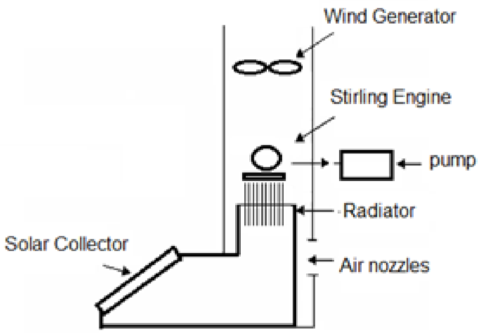

Figure 3 – Model of an upgraded greenhouse generator

Thus, the joint model allows both generating mechanical energy for agricultural water supply and generating electrical energy. If necessary, it is possible to use this installation for heat supply and hot water supply of buildings in rural areas. It is established that the intensity of the conversion of radiant energy into mechanical energy can vary due to the optimization of the peripheral angular momentum along the height of the vortex near the underlying surface. Using the swirling air flow, you can increase the efficiency of the greenhouse generator.

The proposed model does not contain a salt pond and an ice pit. The concentrators have been replaced with solar collectors, which do not require automatic control when the position of the sun changes. Their design is simplier and more reliable in operation.

Another very important advantage is the versatility of using such an installation. It can generate mechanical, electrical, and thermal energy simultaneously with the priority of some type of energy. An integrated approach to generating various types of energy allows us to solve the problem of autonomous provision of detached buildings and structures.

Conclusion

Based on the results of the study, the following conclusions can be drawn:

1 Environmental policy is a priority direction of the state's development, meets modern global trends in the field of energy conservation and the development of green energy. The geographical location and economic specifics of the region assume the development of autonomous systems based on renewable energy for electricity, heat and water supply;

2 Agricultural industries are developing in Kostanay region, mainly small peasant farms that require small energy capacities while generating electric and thermal energy at the same time;

3 For autonomous power supply, it is proposed to use a greenhouse power plant, which can be improved to generate electrical, mechanical and thermal energy for agricultural needs and household consumption;

4 It is possible to develop both stationary and mobile designs of autonomous energy systems based on a greenhouse generator.

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Material received on 20.06.23.

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Материал 20.06.23 баспаға түсті.

АВТОНОМДЫ ЭНЕРГИЯМЕН ҚАМТАМАСЫЗ ЕТУ ҮШІН БАЛАМА ТЕХНОЛОГИЯЛАР

Мақалада Қостанай облысында ауыл шаруашылығы саласында қолдану үшін жаңартылатын энергия көздерінен жұмыс істейтін дербес энергия жүйелерін пайдаланудың өзектілігі қарастырылған. Халықтың тығыздығы төмен және дамыған ауыл шаруашылығы кезінде оларды құрудың ұтымдылығы тұрғысынан энергиямен қамтамасыз ету жүйелерінің негізгі ерекшеліктері қаралды.. Электр энергиясын өндіруге байланысты электр энергиясының өзіндік құны мен тарифтері құрылымындағы құраушының үлесі келтірілген. Ауыл шаруашылығы өнімдерін өндіруде электр энергиясына жұмсалатын шығындардың үлесі айқындалды және оларды төмендету жолдары белгіленді. Ауыл шаруашылығын сумен жабдықтау үшін гибридті автономды энергия қондырғыларын пайдалану мүмкіндігі қаралды. Гелиомет пен парниктік генератордың көмегімен жылу, механикалық және электр энергиясын өндірудің балама технологияларының құрылғысы, жұмыс принципі ұсынылған. Қарастырылған балама технологиялардың артықшылықтары мен кемшіліктеріне салыстырмалы талдау жүргізілді, соның негізінде қолданыстағы конструкцияларға құрылымдық өзгерістер мен толықтырулар ұсынылды. Стирлинг қозғалтқышын парниктік генератормен бірге механикалық энергия алу үшін пайдалану ұсынылады, бұл жел генераторы арқылы электр энергиясын өндіруге мүмкіндік береді. Жаңартылатын энергияны пайдалануға мүмкіндік беретін түпнұсқалармен салыстырғанда гибридті құрылымның негізгі артықшылықтары мен әмбебаптығы атап өтілді.

Кілтті сөздер: күн энергиясы; жел энергиясы; гелиомет; парниктік генератор; энергиямен жабдықтау жүйелері.

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Материал поступил в редакцию 20.06.23.

АЛЬТЕРНАТИВНЫЕ ТЕХНОЛОГИИ ДЛЯ АВТОНОМНОГО ЭНЕРГООБЕСПЕЧЕНИЯ

В статье рассмотрена актуальность использования автономных энергосистем, работающих от возобновляемых источников энергии, для применения в сельскохозяйственной отрасли в условиях Костанайской области. Рассмотрены основные особенности систем энергообеспечения с точки зрения рациональности их построения при низкой плотности населения и развитом сельском хозяйстве. Приведена доля составляющей в структуре себестоимости и тарифов на электроэнергии, связанная с генерированием электричкой энергии. Определена доля затрат на электрическую энергию в производстве сельскохозяйственной продукции и намечены пути их снижения. Рассмотрена возможность использования гибридных автономных энергоустановок для водоснабжения для сельскохозяйственных нужд. Представлены устройство, принцип действия альтернативных технологий получения тепловой, механической и электрической энергии с помощью гелиоводомета и парникового генератора. Проведен сравнительный анализ достоинств и недостатков рассмотренных альтернативных технологий, на основе которых предложены конструктивные изменения и доработки в существующие конструкции. Предложено использование двигателя Стирлинга для получения механической энергии в совокупности с парниковым генератором, позволяющих посредством ветрогенератора вырабатывать электрическую энергию. Отмечены основные преимущества и универсальность гибридной конструкции, в сравнении с исходными, позволяющей использовать возобновляемую энергию.

Ключевые слова: энергия солнца; энергия ветра; гелиоводомёт; парниковый генератор; системы энергоснабжения.

Теруге 20.06.2023 ж. жіберілді. Басуға 30.06.2023 ж. қол қойылды.
Электрондық баспа
17,5 Mb RAM
Шартты баспа табағы 22,67. Таралымы 300 дана. Бағасы келісім бойынша.
Компьютерде беттеген: А. Мыржикова
Корректор: А. Р. Омарова
Тапсырыс № 4103

Сдано в набор 20.06 2023 г. Подписано в печать 30.06 2023 г.
Электронное издание
17,5 Mb RAM
Усл. печ. л. 22,67. Тираж 300 экз. Цена договорная.
Компьютерная верстка: А. Мыржикова
Корректор: А. Р. Омарова
Заказ № 4103

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