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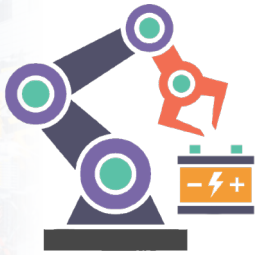

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Improving the Efficiency of Photovoltaic Modules of a Solar Power Plant for Power Supply to Autonomous Rural Consumers

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***Abstract.** The article reviews one of the development stages of the hybrid wind-solar power plant for power supply of the autonomous rural consumers with a capacity up to 1 kW. The results of the photovoltaic modules efficiency during their heating and contamination analysis are presented. A model of a hybrid wind-solar power plant is proposed for consideration, where the wind wheel is combined with a frame for fixing the PVM. The blades are foldable and made of transparent plastic for reducing the resistance for the oncoming flow, which increases the speed of rotation of the wind wheel. An increase in the efficiency of photovoltaic modules and a reduction in their degradation is achieved due to their rotation around the axis of a truncated pyramid with an octagonal base. A laboratory model was constructed for conducting field experiments and testing the design of the security system. The obtained research results allow to further create an operating hybrid renewable energy source and search for the most rational design.*

***Keywords:** photovoltaic module, wind-solar installation, wind wheel, orientation by the sun, wind generator, wind speed, power, tracking system.*

Introduction

The issues of improving the photovoltaic modules (PVM) efficiency is important for achieving the highest technical and economic characteristics of solar power plants (SPP). One way to increase the efficiency of PVM is their spatial orientation control by

a tracking system for the movement of the sun across the sky during the day. Orientation systems can be of several types, mainly they are one or two-axis solar trackers, which, according to various literatures, can increase in the volume of electrical energy products per day up to 70% [1, 2]. Another option for improving the efficiency of the tracking system work is the use of a two-way sensitive PVM, when the tracking system is not needed, which, according to various evaluations, will increase the cost of SPP up to 2.5 times [1]. There are also a number of unresolved problems related to the contamination of the surface of the PVM and the need for cleaning them, which increases the cost of operating the SPP [1, 2]. It should also be noted that the heating of PVM by the rays of the sun during the day above 25°C leads to a decrease in their efficiency and the development of degradation. An increase in temperature by 1°C from 25°C reduces the power of the solar panel to about 0.2% [1]. When the panels are blown by the wind, their temperature may decrease, which has a positive effect on their efficiency. In the conditions of Karaganda, there is a high dustiness and the frequency of cleaning should be at least once a week, otherwise the performance of the SPP will decrease from 10 to 90% depending from the surface contamination, with a vertical arrangement the panels get less contaminated [1, 2]. Considering the above, a hypothesis arose that the PVM can be installed on the side faces of a rotating pyramid with a hexagonal base. At the same time, the PVM are located under the transparent blades of the wind wheel. The idea of creating a combined renewable source is justified by the fact that the PVM is more productive in the summer, and the wind generator in the winter [1]. When the wind wheel rotates, the PVM rotates simultaneously, which are exposed to the direct rays of the sun for a certain period of time. The aim of the work is to create a working model of a hybrid renewable energy source for conducting research and searching for the most rational design.

Research methods and materials

A working model of a renewable source was specially developed for empirical research. The model is a hybrid wind-solar power plant (HWSPP), which has a number of significant differences from the analogues already known and used in practice. The wind wheel is combined with a frame in the form of a truncated pyramid with an octagonal base on the side faces of which are fixed PVM. The blades of the wind wheel are made of transparent plastic folding to reduce the resistance to the oncoming flow, which increases the speed of rotation of the wind wheel, and also allows solar radiation to penetrate the working surface of the PVM. During the rotation of the wind wheel, its blades rise, completely opening the PVM, and then fold under the influence of gravity, which reduces their drag and solves the important problem of increasing the rotation frequency of the wind wheel with a vertical axis [3, 4]. When the wind wheel rotates, only 1 or 2 blades are active, and the rest are in the folded position, which allows to increase the rotation speed of the virial wind generator to 1000 rpm. Figure 1.a shows the design of a folding blade that rises from the wind flow and returns to the transport position under gravity. Figure 1.b shows the state of the HWSPP model when all the blades are folded, as well as some measuring devices involved in the research.

Information about the design of the HWSPP and the principle of operation and the main differences from analogues can be found in the source [5]. The base of the model is made of plywood with a thickness of 9 mm, on which the coils of a synchronous electric generator on permanent magnets and the axis of rotation of the wind wheel are installed.

During the experiment, the synchronous generator was disconnected from the load and rotated in idle mode.

Eight PVM rotates around the axis with a power of 0.5 W (Uh.i. = 5V) each as the energy is transferred to the load using two brass rings with brushes. The load was LED lamps with a total power of 2 watts. PVM installed on the side faces of the octagonal pyramid. The blades and other parts of the wind wheel are made of ABS plastic with 3D printing. The following measuring instruments were used in the research process: UT50C and UT 202 multimeters, Victor 6234P rotation frequency sensor, FNB48S PD DC power measurement microcontroller, RZ-816 anemometer, pyrometer With 20.3, light meter AR823. A Makita UB1103 vacuum cleaner blower (650 W, 4.1 m^3/h) was used to create the wind flow. PVM inclined at an angle of 50°, which corresponds to the latitude of the city of Karaganda, where the tests were conducted. The weather is clear without clouds, the ambient temperature was 22°C. The illumination of the PVM surface was 10100 Lux. Figure 2 shows the electrical diagram of the PVM and the load connections.

Research results

The results of the study are a graph of the PVM current growth dependence from the wind wheel speed (Figure 3). When processing experimental data and plotting, the capabilities of the Microsoft Excel program were used.

During the rotation of the wind wheel around its axis with the PEM fixed on it, it was found that the highest power achieved at 600 rpm, which was achieved at an air flow speed created by the Makita UB1103 blower within 18 m/s. The maximum speed can reach 1000 rpm, with an air flow speed of about 28 m/s. There was an increase in voltage from 3.82 V and a current of 0.13 A at a stationary position (0 rpm), to 4.3 V and a current of 0.21 A at 600 rpm. With a further increase in the rotation speed, a decrease in power was observed. During rotation, the temperature of the PVM decreases in the range of 11-12°C. HWSPP can be used to supply electricity to autonomous consumers of rural areas with a capacity of up to 1 kW, which can be farms and parking lots of animal husbandry. If necessary, the amount of HWSPP

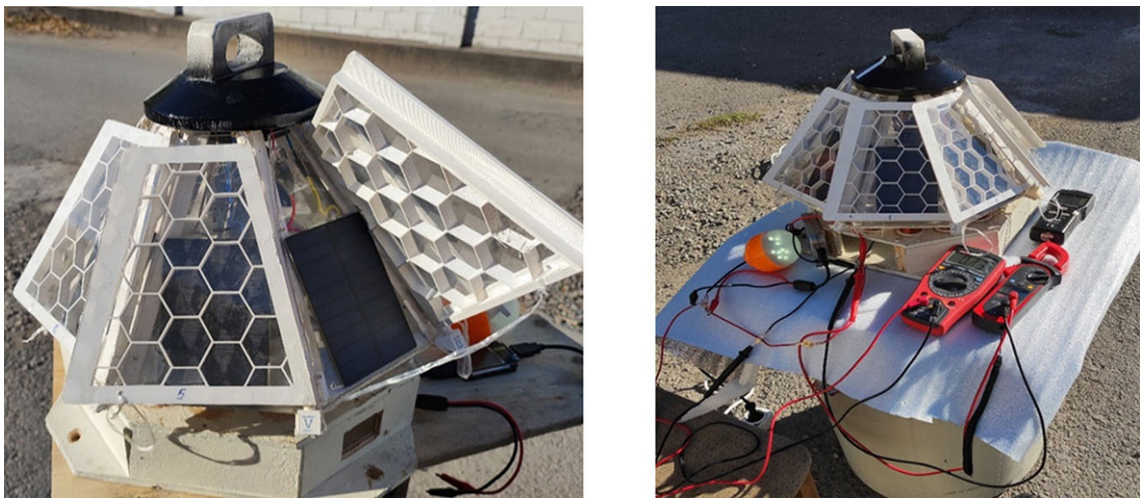

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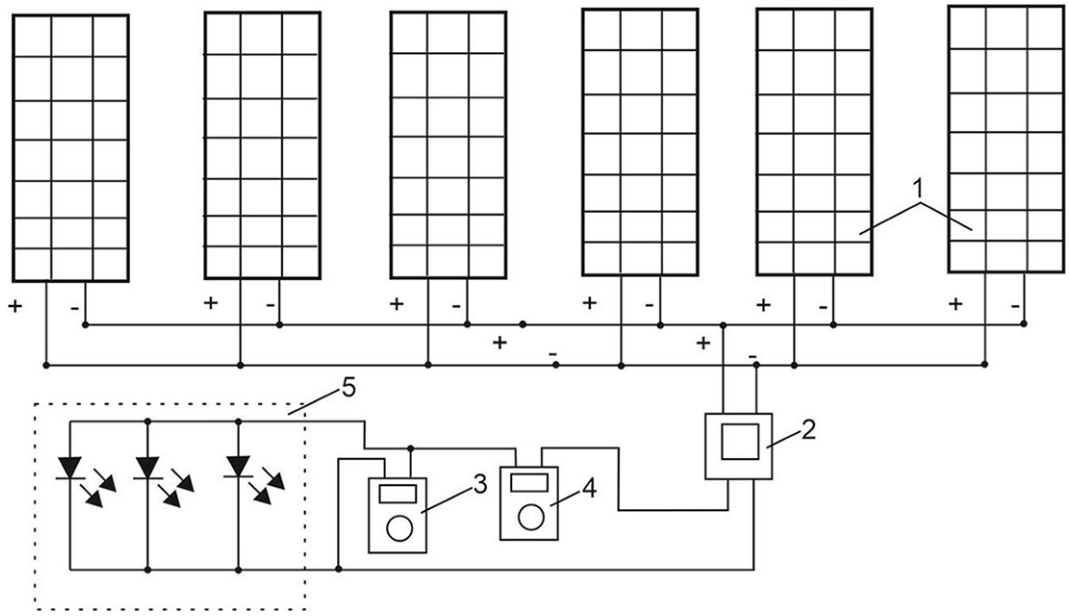
Figure 1 – Model of a hybrid wind-solar power plant (HWSPP)



1 – PVM; 2 – controller; 3 – multimeter for voltage measurement; 4 – multimeter for current measurement; 5 – electrical load

Figure 2 – Electrical diagram of the PVM connection and load connection

can be increased to the desired level of electric energy production. The wind generator and the PVM work on the same drive, which is a battery with a voltage of 12 V, but if necessary, you can switch to another DC voltage. The electrical circuit of the HWSPP basically has an already known layout using a charge controller, a storage device and an inverter [1, 3], but differs in the presence of a dedicated DC line with a voltage of 12 V. This allows you to directly power various electronic devices running on direct current, without using network adapters and connecting them to a network inverter. One of the variants of the HWSPP circuit is shown in Figure 4, which shows the separation of the load according to the type of current, to reduce the power of the inverter, and accordingly its cost [1, 3].

There is no need to power the charger of a cell phone or laptop and other devices from an inverter. The same applies to LED lamps, which can operate on direct current and without drivers for much longer. The voltage of the HWSPP can be selected, if necessary, for a specific consumer in the range from 12 to 72 V. What will make possible to charge the batteries not only of electronic gadgets, but of various vehicles (electric bicycle, electric scooter, electric scooter, etc.). If necessary, the energy from the HWSPP battery can be converted into alternating current using an inverter for short-term power supply of a low-power electric tool or use the battery for short-term welding work. To reduce the cost of the HWSPP and simplify

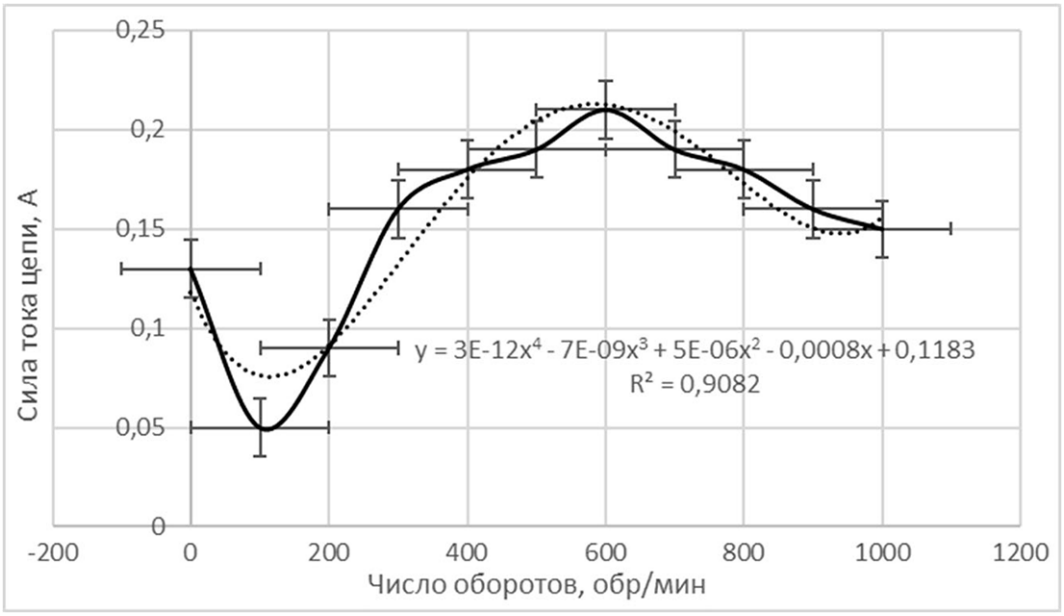


Figure 3 – Graph of the dependence of the growth of the current strength of the PVM on the speed of the wind wheel

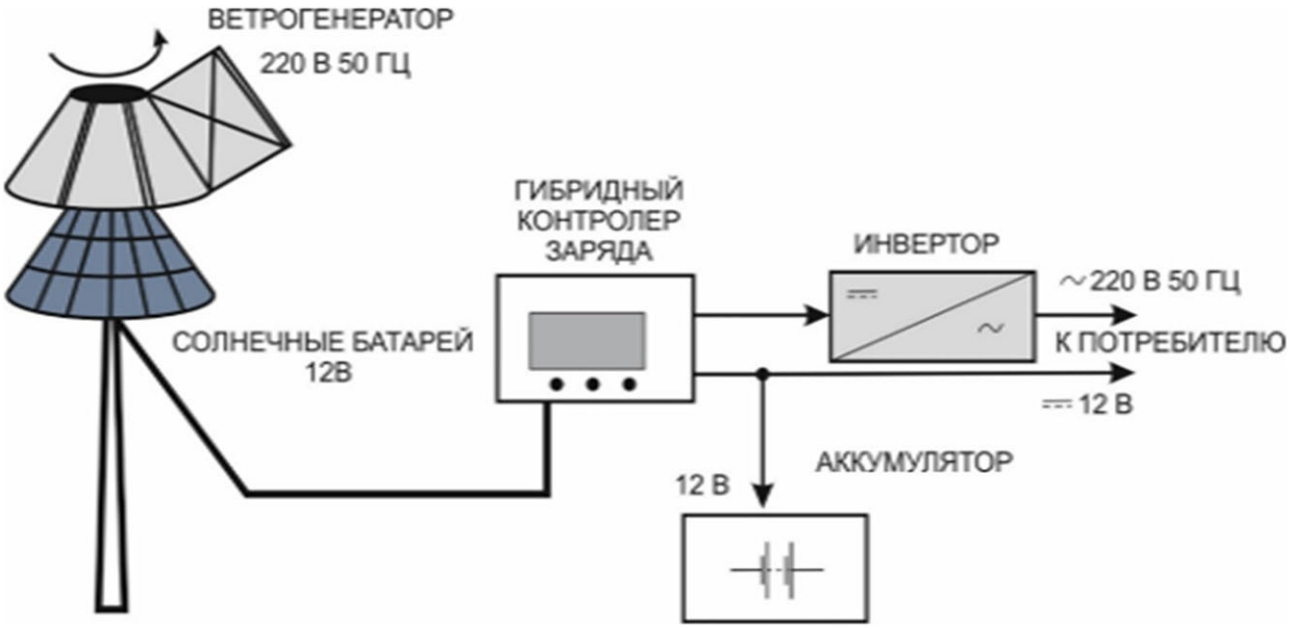


Figure 4 – Scheme of HWSPP

its operation, it is recommended to use a voltage of 12 V. The generated electrical energy will be stored in a battery with a voltage of 12 V. For this, the voltage of the synchronous generator and solar panels will be about 14 V. Car batteries with a capacity of 50-200 Ah can be used as an energy storage device.

Conclusions

The use of HWSPP is justified, since wind and solar energy is being converted at the same time, taking into account that in central Kazakhstan in winter and autumn the wind generator is more efficient, and in spring and summer more energy is generated by more efficient solar panels. The HWSPP model has shown its efficiency and the ability to achieve relatively high revolutions (up to 1000 rpm) for wind wheels with a vertical axis of rotation. The rotation of the PVM makes it possible to perform their constant orientation to the sun and increase the generated power of the SPP, in contrast to the stationary mode, by an average of up to 60%, which is quite comparable to using a biaxial tracker. The HWSPP has a better aerodynamic performance and less windage compared to the tracker, which will reduce the cost

of the tracking system design. The proposed design of the HWSPP is more adapted to the gusty winds of the Central Kazakhstan and is able to withstand wind speeds up to 30 m/s without destruction. When the PVM rotates, they are provided with better cooling and dust removal, which is important for improving the efficiency of the SPP. In the process of carrying out, a number of flaws in the design of the HWSPP were identified, which were eliminated in the future, first of all, this concerns the paws, since their cellular structure obscures the PVM. It should also be noted that at the stationary position of the PVM, its surface was heated to a temperature of 43°C, and during rotation it decreased to 31°C, which indicates a positive moment in achieving the cooling effect of the PVM, which means a reduction in degradation and an increase in efficiency.

REFERENCES

1. Ways to improve the efficiency of solar power plants. Monograph / A.V. Yurchenko, A.D. Mekhtiev, A.D. Alkina; Karaganda State Technical University. – Karaganda: Publishing House of KSTU, 2017. – 181 p.
2. Tremyasov V.A., Photovoltaic and hydropower installations in autonomous power supply systems: monograph / V.A. Tremyasov, K.V. Kenden. – Krasnoyarsk: Sib. feder. un-t, 2017. – 208 p. ISBN 978-5-7638-3539-7
3. Bubenchikov A.A., Belodedov A.E., Bulychev I.S., Shepelev A.O. Study of aerodynamics and energy characteristics of the Savonius rotor. International Research Journal. No. 12 (54). Part 3. 2016. DOI: 10.18454/IRJ.2016.54.266
4. Faizan A. Khan, Nitai Pal, Syed H. Saeed. Optimization and sizing of SPV/Wind hybrid renewable energy system: A techno-economic and social perspective. https://doi.org/10.1016/j.energy.2021.121114 0360-5442/© 2021 Elsevier Ltd. All rights reserved
5. Olzhabay A.Sh., Mehtiev A.D. Charger «Winged Rotor». Utility model patent No. 5991. Date of issue 04/16/2021

Автономды ауыл тұтынушыларын электрмен қаттамасыз ету үшін күн электр станциясының фотоэлектрлік модульдерінің жұмыс тиімділігін арттыру

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***Аңдатпа.** Қуаттылығы 1 кВт-қа дейінгі ауылдық елді мекендердегі автономды тұтынушыларды электрмен жабдықтау үшін гибридті жел-күн электр станциясының үлгісін әзірлеу қарастырылады. Шетелдік өндірушілер әзірлеген қолданыстағы фотоэлектрлік модульдердің тиімділігінің талдауы келтірілген. Қарау үшін гибридті жел-күн электр станциясының үлгісі ұсынылады, мұнда жел дөңгелегі РЕМ орнатуға арналған жақтаумен біріктірілген, ал оның қалақтары мөлдір пластиктен жасалған. Гибридті жел-күн электр станциясының жұмыс істеу принципі фотоэлектрлік модульдердің тиімділігін арттыруға және олардың тозуын азайтуға негізделген. Толық ауқымды эксперименттер жүргізу және қауіпсіздік жүйесінің жобасын әзірлеу үшін зертханалық модель әзірленді. Зерттеу нәтижелері зерттеу және ең ұтымды дизайнды іздеу үшін гибридті жаңартылатын энергия көзінің жұмыс моделін одан әрі құруға мүмкіндік береді. Гибридті жел-күн электр станциясының ұсынылып отырған жобасы Орталық Қазақстанның екпінді желдеріне көбірек бейімделген және желдің жылдамдығы 30 м/с-қа дейін бұзылмай төтеп бере алады.*

***Кілт сөздер:** фотоэлектрлік модуль, қалақ, жел дөңгелегі, күн бағдары, жел генераторы, жел жылдамдығы, қуат, бақылау жүйесі.*

Повышение эффективности работы фотоэлектрических модулей солнечной электростанции для электроснабжения автономных сельских потребителей

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***Аннотация.** Рассматриваются вопросы разработки модели гибридной ветро-солнечной электростанции*

для электроснабжения автономных потребителей сельской местности мощностью до 1 кВт. Приводится анализ эффективности работы существующих фотоэлектрических модулей, разработанных зарубежными производителями. Предлагается к рассмотрению модель гибридной ветро-солнечной электростанции, где ветроколесо совмещено с каркасом для крепления ФЭМ, а его лопатки выполнены из прозрачного пластика. В основе принципа работы гибридной ветро-солнечной электростанции лежит повышение эффективности работы фотоэлектрических модулей и снижение их деградации. Для проведения натурных экспериментов и отработки конструкции охранной системы была сконструирована лабораторная модель. Полученные результаты исследования позволяют в дальнейшем создать действующую модель гибридного возобновляемого источника энергии для проведения исследований и поиска наиболее рациональной конструкции. Предлагаемая конструкция гибридной ветро-солнечной электростанции более адаптирована к порывистым ветрам центрального Казахстана и способна выдержать скорость ветра до 30 м/с без разрушения.

Ключевые слова: *фотоэлектрический модуль, лопасть, ветровое колесо, ориентирование по солнцу, ветрогенератор, скорость ветра, мощность, следящая система.*

REFERENCES

1. Ways to improve the efficiency of solar power plants. Monograph / A.V. Yurchenko, A.D. Mekhtiev, A.D. Alkina; Karaganda State Technical University. – Karaganda: Publishing House of KSTU, 2017. – 181 p.
2. Tremyasov V.A., Photovoltaic and hydropower installations in autonomous power supply systems: monograph / V.A. Tremyasov, K.V. Kenden. – Krasnoyarsk: Sib. feder. un-t, 2017. – 208 p. ISBN 978-5-7638-3539-7
3. Bubenchikov A.A., Belodedov A.E., Bulychev I.S., Shepelev A.O. Study of aerodynamics and energy characteristics of the Savonius rotor. International Research Journal. No. 12 (54). Part 3. 2016. DOI: 10.18454/IRJ.2016.54.266
4. Faizan A. Khan, Nitai Pal, Syed H. Saeed. Optimization and sizing of SPV/Wind hybrid renewable energy system: A techno-economic and social perspective. https://doi.org/10.1016/j.energy.2021.121114 0360-5442/© 2021 Elsevier Ltd. All rights reserved
5. Olzhabay A.Sh., Mehtiev A.D. Charger «Winged Rotor». Utility model patent No. 5991. Date of issue 04/16/2021