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Autonomous hybrid power plants based on renewable and traditional sources of electricity

ABSTRACT: The purpose of this study is to consider a passive balancing system for battery storage which in the future will increase their reliability, reduce maintenance costs, reduce wear and tear and increase service life, as well as to study a new method of quasi-opposition search for harmony in order to stabilize the supplied electricity. To this end, various theoretical methods of scientific study (analysis, concretization, comparison, generalization) were applied. The method considered in this article for improving the performance of batteries using a passive balancing system, using the example of a typical structural diagram of an autonomous hybrid power plant presented here, would increase the efficiency of pre-project work on the development of highly efficient design and circuit solutions and increase the battery life. The new method of quasi-opposition searches for harmony

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for hybrid power plants based on renewable and traditional energy sources, taking into account features of their design and operation, would make it possible to stabilize the load frequency of the consumer at the time of switching the station between power sources. This study can be useful for the circle of people associated with energy, for students studying renewable energy in higher education institutions, as well as their teachers, in order to familiarize themselves with the problems of hybrid stations and find options for their solutions.

KEYWORDS: power plant, inexhaustible resources, batteries, load frequency, balancing system

Introduction

Kyrgyzstan has great potential for renewable energy development in several key areas. The use of renewable energy can help Kyrgyzstan reduce its dependence on imported fuels and contribute to global sustainable development goals, including the reduction of carbon emissions. However, political will, investment and technological solutions are needed to develop renewable energy in the country. In recent years, the idea of environmental friendliness and the feasibility of using renewable resources to generate electricity has been actively developed and promoted; however, according to the studies discussed below, over the past decades, the percentage of electricity produced using such resources has increased slightly (Havrysh et al. 2020). Furthermore, thanks to the strategies of the EU and the UN to introduce alternative energy and reduce emissions of toxic substances, there has been a twenty-two fold increase in total wind power around the world from 2001 to 2017 (23,900 to 539,000 MW), and solar power in the decade 2007–2017 achieved a growth of 4,300%. However, due to the COVID-19 pandemic and other factors, the total energy consumption generated from renewable sources in the period 2020–2021 increased only by 0.1% from 22.1 to 22.2% (Global Energy Review 2021 2021; Share of energy consumption… 2022).

Optimization techniques in stand-alone hybrid power plants offer key benefits and potential. They enhance plant efficiency by effectively utilizing various technologies and combinations of energy sources. They aid in intelligent resource management, allowing the system to auto-adjust operation considering current energy demand, atmospheric conditions, wind speed, and more. These methods support the flexibility of energy systems, maintaining balance between energy production and consumption, and facilitating the integration of renewables for better stability and reliability (Kondratenko et al. 2018). Economically, optimization can reduce energy production costs, thus increasing competitiveness and also helping to cut down maintenance costs due to efficient resource usage. Research by Mehta et al. (2022a) shows that due to its favorable geographical location and landscape features, Kyrgyzstan has great potential for the development of power plants based on renewable energy sources (RES), as well as hybrid stations based on traditional and renewable sources (Botpaev et al. 2011; Mustaeva and Kartayeva 2019). The resource assessment of Kyrgyzstan by Mehta et al. (2022a), Mustaeva and Kartayeva (2019)

shows that this is facilitated by the presence of large and medium-sized rivers, the potential of hydropower, which is estimated at 80 billion kWh. per year, as well as numerous rivers and mountain flows (2,047), about 5–8 billion kWh. in year. Geothermal sources are mainly sanitary-resort properties and have a low-temperature nature of thermal resources of 55–60°, which is why they do not look like an expedient option for energy production. Since Kyrgyzstan is an agrarian state, it has fairly high potential for biomass energy. Currently, there are approximately 1.5 million heads of cattle in the country, which are the main source of this resource.

According to the study by Baybagyshov and Degembaeva (2019), together with the percentage of growing agricultural plants, the potential is estimated at about 9.732 thousand TJ per year. Forests occupy about 5.6% of the total territory of the state, or approximately 1.2 million hectares; however, according to experts, it is not suitable for use in the energy sector due to its seasonality and remoteness from settlements. The wind speed in the suburbs of Kyrgyzstan reaches a maximum speed of 13 m/s, which is not enough for full-fledged year-round consumption of stations, and the supply of electricity from mountainous areas is an economically unprofitable strategy. Furthermore, the intensity of solar radiation in the country, as indicated in the works of Sadykov et al. (2018) and Suyundukov and Sadykov (2020) does not fluctuate much due to the favorable geographical location and reaches up to 1,084 W/m^2. The work of Dykes et al. (2020) shows that autonomous hybrid power plants, due to their stability and fairly rapid development, are an excellent solution for several currently important issues at the same time. Such as: environmental pollution, the depletion of natural resources (fossils), economic unprofitability, fragility, the inability of power plants based on classical methods of energy production to quickly adapt to changes in demand, as well as instability and seasonality of plants based on renewable sources (Stavinskii et al. 2019).

The problem lies in the most expensive and short-lived part of such hybrids – batteries. Their fragility lies in sharp changes in charge values, due to which, after 1–2 years after installation, the battery volume is halved, and after a couple of years, they need to be changed, which ultimately causes economic and environmental problems. The purpose of this study is to consider a passive balancing system based on solar photovoltaic plants to improve reliability and increase battery life. It will also evaluate a new quasi-oppositional harmony search algorithm (QOHSA) system and its feasibility in comparison with a teaching learning-based optimization algorithm (TLBOA) to stabilize the load frequency of a hybrid power plant with multiple batteries and power units (Tarkeshwar and Mukherjee 2015). In the future, it would enable stabilization of the load frequency of the consumer network during the switching of the power plant from one source to another.

1. Materials and methods

While working on the study, methods such as analysis, evaluation, concretization, and generalization were used to process the studied information. The combination of different theoretical methods helped to qualitatively study the problems of autonomous hybrid power plants and propose solutions. The aspects of the operation of autonomous hybrid power plants based on alternative and exhaustible sources of electricity are considered and analyzed. The features of hybrid power plants on traditional and renewable energy sources and stations on alternative sources, their differences, advantages, and disadvantages in comparison with each other are determined. Additionally, the feasibility of using autonomous hybrid power plants at the current time in the world and specifically in Kyrgyzstan was the basic aspect of the beginning of the study. Potential data of the country in the field of alternative energy was considered, analyzed and summarized. An assessment and a comparison of renewable energy sources were performed, as well as an abstract study of the geography, climate, and policy of Kyrgyzstan in this direction, an analysis of the geographical location, a study of hydropower, assessment of the potential of wind energy, solar energy and biomass energy, a generalization of data about them and a comparison of the feasibility of their use. A study of autonomous hybrid power plants based on alternative and traditional sources of electricity in such countries as Kyrgyzstan, the USA, Poland, Japan, Germany, China, and others was conducted in order to assess their impact on the environment and the economy. Additionally, analysis and filtering were performed in relation to the literature on different methods of producing alternative electricity.

Batteries in stand-alone hybrid installations with multiple power units and energy storage devices were considered, and their performance and potential for improvement were evaluated and analyzed. Evaluation and analysis of the problem of loss of energy intensity, as well as the problem of reducing the life of batteries as a result of frequent jumps in charge indicators, was conducted. The main difference between power plants based on alternative or traditional sources of electricity was considered and analyzed – the stability of the supply of electricity to the consumer, in the case of an autonomous hybrid power plant. A passive balancing system was discussed using the example of an autonomous hybrid power plant with a power system of four batteries with a capacity of 3kVA and a battery voltage of 48V. Also considered was the operation of the proposed system in combination with a power system with an increased number of batteries. The system of a quasi-oppositional method of finding harmony based on the development of a frequency controller has been researched and evaluated in order to stabilize the load frequency of the consumer when switching an autonomous hybrid installation from alternative sources to a diesel piston generator. It was compared with a harmony search system developed on the basis of training currently used in similar power plants.

The collected data was analyzed and systematized for further simplified and qualitative understanding of the information. A systematic analysis of the methods used to produce electricity using alternative energy sources was conducted. An analytical comparison of renewable energy sources was performed in order to determine the best autonomous hybrid power plants for the

most efficient operation. The findings were analyzed, systematized and summarized for easier understanding in the context of the current work.

2. Results

To date, renewable sources have been intensively introduced into autonomous power supply systems (Bórawski et al. 2019; Qazi et al. 2019; Murdock et al. 2021). The active introduction of RES in the power-supply sector is determined by the following three reasons (Climate Profile of… 2014; Brodny et al. 2021; Al-Shetwi 2022):

✦ environmental problems associated with the extraction and processing of traditional energy resources (a large amount of equipment, human resources, processing of extracted resources);

✦ the limited nature of their reserves (traditional energy resources are currently being exhausted faster than they are being formed, since it often takes centuries to form them);

✦ unlimited renewable energy resources.

A real opportunity to improve the technical and economic performance of autonomous power plants is the use of inexhaustible energy sources. In particular, the use of solar energy, photovoltaic stations and autonomous hybrid power plants developed on their basis (Mehta et al. 2022b). An important factor for their use is that the cost of photovoltaic plates over thirty-five years (1980–2015) has decreased by more than fifteen times (Borisov et al. 1998; Li et al. 2022). Kyrgyzstan has a high energy potential based on renewable energy sources (RES), estimated at 840.2 million watts per year. Potential renewable sources are solar energy, wind energy, energy from small rivers and mountain run-off, and biomass energy. However, in the energy balance of the country, at present, they do not reach even 1% in use. This is due to various reasons, the main one being the weak incentives for clean energy by the government. Due to the favorable geographical location of Kyrgyzstan and pleasant climatic conditions, the territory of the country receives an average of 4.64 billion MW of radiant solar energy per year, or 23.4 kW/h per 1 sq. m., and the average annual duration of sunshine reaches from 2,100 to 2,900 hours, depending on the region. Experts say that solar energy has great potential for real use in the energy industry. The expediency of RES development in Kyrgyzstan is due to the following reasons:

✦ the growing shortage of traditional fuel and energy resources;

✦ the growth of dynamics of electricity prices.

It follows that at present, the issue of studying and systematizing the renewable energy potential of the territory, improving the methods for choosing equipment and optimizing autonomous power plants based on renewable energy sources is relevant (Tarkeshwar and Mukherjee 2015; Bórawski et al. 2019). Combined, hybrid autonomous power supply systems using solar and wind energy, as well as a diesel or gas piston generator as a backup source, have great potential. In addition, alternative energy sources make it possible to get closer to solving the problem of

energy supply to remote villages and farms in Kyrgyzstan, which account for more than half of the country's territory. Today, it is known that autonomous hybrid power plants based on different types of electricity sources have a significant economic effect. The best option for autonomous hybrid power plants is a system containing several sources of electricity generation, two of which are alternative solar and wind power plants, and one is a traditional gas piston or diesel power generator (Sadeghi and Askari 2019; Kusznier 2023). A block diagram of autonomous hybrid power plants is shown in Figure 1.
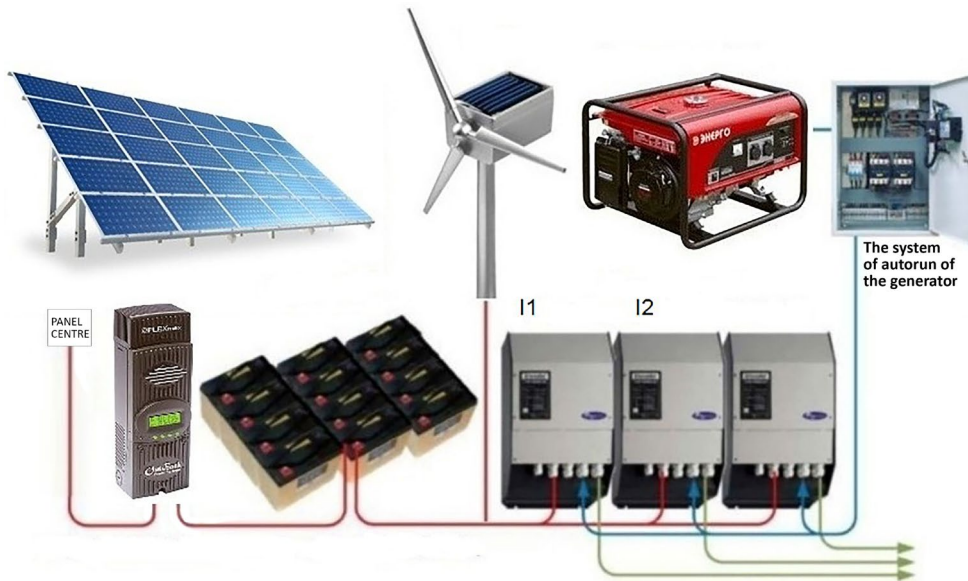

Fig. 1. Typical block diagram of off-grid hybrid power plants

Rys. 1. Typowy schemat blokowy off-gridowych elektrowni hybrydowych

The system works according to the following principle: all the electricity converted by solar panels, through the network inverter I1, with a nominal voltage of 220 V, is supplied for power to the power supply system. The main tasks of the I2 hybrid inverter (capable of directing energy flows in both directions) are to charge the batteries of a traditional generator and generate electricity for the load, converted from batteries in the event of a lack of voltage or insufficiency from alternative sources. In situations where the energy received from solar and wind panels exceeds that consumed to power the loads, its excess goes to charge the batteries, and when the batteries are fully charged, they can power additional loads.

Between the two-day energy options available in the battery in the case of cloudy and calm weather at 50% battery discharge (actually three days with a deep discharge) and the daily discharge option, but at 30%, something in between is usually chosen (discharge battery more than 25% daily – unacceptable). The performance and service life of batteries depends not only on the

number of full discharge cycles, but also on the temperature during their operation (if it exceeds 45°C, their service life is reduced by a factor of three), as well as on the quality of the network charger unit, which should provide at least three battery charges in a stepwise mode until full. In addition, the inverter (a device designed to convert to AC 220 V, 50 Hz, DC batteries) has special requirements. In total, the load power should not rise above 75–80% of the rated output power of the inverter specified in its characteristics (Sadykov et al. 2018; Suyundukov and Sadykov 2020).

Inverter I1 converts the direct current received from the solar panels into an alternating current with a voltage of 220. The output of this current is connected to the common load circuit. Only if there is AC generation by inverter I2, does it have the ability to generate a sinusoidal current; however, inverter I2 can turn off in case of overload, overheating or due to deep battery discharge (for example, by 90%). To prevent this, the inverter control system will give a command to start the conventional generator at a less deep charge (for example, about 40%). With a successful start, the generator will begin to supply voltage and power the connected loads, and the inverter, thanks to the built-in charger unit (CH), will charge the batteries to a certain level. The charger can reach a power of up to 5 kW.

When using an autonomous hybrid power plant, it is required to take into account the normal operation of diesel generators and the conditions for its implementation – the total power of the connected loads should not exceed 80% of the rated power. The protective circuit breaker prevents the use of unauthorized power loads. In case of an overload, the voltage supply from the diesel generator will be turned off, but after twenty seconds it will resume and, if the overload persists, the generator will stop. It will be possible to restart the generator if the load is removed and it is started in the manual mode. In this case, the battery is charged, on the one hand, by the inverter I2, receiving energy equal to the difference between the received solar energy and the consumed load, in real time from the network connection with the inverter I1 in the daytime, but not more than allowed, set by the system controller (SC). At the same time, at a certain discharge, also programmed by the system controller, the battery is charged through the I2 inverter after starting the traditional generator, with the charging current limits also set. In the case of a day charge, the battery can be fully charged, i.e. 100%, if the inverter manages to perform three stages, which is possible in summer, when there is a slight reset at night.

Also included in the charge circuit is a wind turbine controller, the tasks of which are to rectify the generator output signal, convert the generator power into the charging current of batteries, provide a three-stage charge mode for realizing a 100% battery charge, dump energy when it is in excess or when there is no load, and also shut down and control the direct current and its loads when the battery charge drops below the permitted level and brakes of the generator during excessive acceleration. The most vulnerable and most expensive link in autonomous hybrid power plants, according to researchers, is batteries. The more of them there are in the warehouse of the system, the more difficult it is to fulfil all the conditions for their correct operation. To extend their service life by about 1.5–2 times, certain conditions must be met. Figure 2 shows a diagram of a 3 kW power plant in which several lead batteries are connected in series. It is worth taking as an example a system containing a 3 kW inverter with a battery voltage of 48 V. Often, such

power supply systems contain four batteries connected in series with a voltage of 12 V and a capacity of 90 to 260 Ah (maintenance-free, lead-acid).
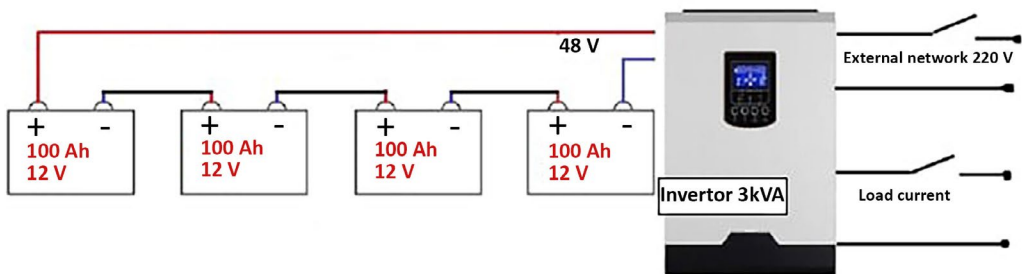
When using the same type of batteries, at the beginning of their operation, the voltage on each battery is almost the same; however, after 5–7 months of use, the initial value of the internal resistance changes in each of them. As an example, we can say that if one battery is not charged, and the other, by contrast, is recharged, then both cases will have an extremely negative effect on them: in the first case, the process of sulfating of the plates will take place, and in the second, the electrolyte would boil away, and the lead mass would crumble, and the imbalance would only increase over time. The main factors of such processes can be production technological deviations of parameters, temperature changes, vibrations, shocks, undercharging or overcharging, as a result of which, the internal resistance changes according to its own law for each battery. At this point in time, the firms that produce batteries with the most minimized technological deviations have been identified. Such batteries would last longer, but for them, it would be required to pay an amount that exceeds the cost of traditional batteries by two times or more.

Due to the fact that the internal resistance of the batteries changes, their service life will decrease. So instead of the prescribed, for example, five to seven years, one battery would lose half of its capacity in one and a half to two years and its use would be inappropriate (U-802… 2021). To prevent such a problem and increase the operating time of the backup source, a system of several batteries is created (Fig. 3). The shown method of connecting batteries saves the situation for a certain period, but the problem cannot be avoided, and as a result, in the future, it would only get worse. As a result, after two to three years of using the power system, it would be required to change all the batteries. In total, on average, for a year of operation of the system, one battery would have to be changed, but if there are several such nodes, half of the batteries would have to be changed from the total number.

To increase the battery life, it is proposed to use a balancing system that would stabilize the voltage on each battery from the beginning of its charge. A technical solution for a passive balancing system for 12-volt lead-acid batteries has been identified. The main criteria for choosing a system are its cost and reliability. The features of the system are as follows:
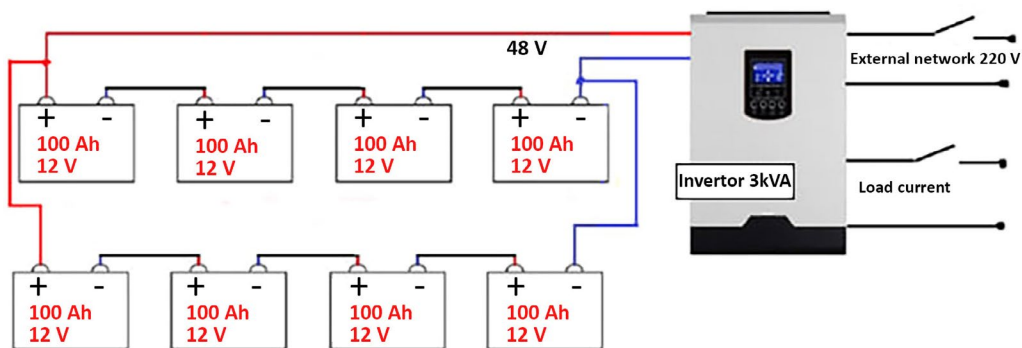
Fig. 3. Battery system for an autonomous hybrid power plant with an increased number of energy storage devices, designed for 3 kW

Rys. 3. Układ akumulatorów autonomicznej elektrowni hybrydowej o zwiększonej liczbie zasobników energii, zaprojektowany dla mocy 3 kW

◆ From the very beginning of charging the batteries, the voltage of the individual batteries in the system is constantly equalized. The system takes into account the voltage on each battery, calculates the average value, and includes an additional (ballast) load on the batteries with high voltage. With the help of this, it is possible to significantly reduce the released power on the ballast load.Each module of the balancing system has its own number, which can be compared with the number of a particular battery. This enables constant monitoring, which in consequence allows visual assessment of the condition and performance of each individual battery, both in the process of charging and in the process of discharging.

◆ It is possible to turn off the load when at least one battery voltage drops below 10.5V (the lower limit of the operating voltage of a 12-volt lead battery).

◆ As a result of the galvanic distribution on the control bus, it is possible to balance several groups of batteries.

◆ The principle of modular design allows adding groups of batteries to a system that is already in operation, and not necessarily from one manufacturer.

The balancing system is selected depending on the battery capacity and charge current. If there is a possibility of forced charging in the power system in two to four hours (for example, from a solar battery or a wind generator), there is a possibility that the balancing system would not have time to extinguish the excess voltage on certain batteries. In this case, the balancing elements must have increased power compared to the standard charge mode. A separate feature of the passive balancing system is that it can be installed on batteries that have been in operation for several years. The effect is due to the fact that an unbalanced system (old batteries) would be mothballed and given the opportunity to work much longer before being replaced.

Modern power systems are becoming increasingly complex every year. Therefore, for the optimal use and management of power systems, it has become necessary to use intelligent optimization methods. In recent years, researchers have begun to apply optimization methods to find

solutions to intractable, elaborate engineering difficulties. Conventional frequency converters cannot provide the desired performance due to the uncertainties associated with generation and load in a stand-alone hybrid power plant. Optimization methods are used to effectively obtain optimal solutions to problems associated with the operation and control of an autonomous hybrid power plant. Researchers are constantly working to improve existing optimization algorithms, and are at the same time looking for new optimization algorithms to efficiently and quickly negotiate complex engineering obstacles. The harmony search algorithm (HSA) is one of the latest additions in this area. HSA is a music-inspired metaheuristic algorithm, and its main principle of operation is the ability of the musician to find the best harmony. Simply put, HSA allows the most efficient domain of decision vectors quickly, and thus it has been adopted by researchers to solve many references engineering/non-engineering problems. However, many empirical studies show that the underlying HSA does not provide the best optimization outcomes. Consequently, several new versions of the HSA have been developed in recent years.

Through an accelerated study of quasi-oppositional learning (QOBL) opportunities, Tarkeshwar and Mukherjee (2015) proposed a quasi-oppositional harmony search algorithm (QOHSA) in which population initialization based on QOBL and generation jumps turned out to be new added options. Roughly speaking, QOHSA is a rapidly evolving QOBL concept included in the standard HSA, which makes it a special and potentially successful optimization algorithm. TLBOA is a newly developed, powerful nature-inspired and parameterless metaheuristic optimization algorithm that mathematically simulates the teaching-learning process between teachers and students in the classroom. Teachers and students are two important pillars of this algorithm. Teachers, being the personification of knowledge, inspire students to improve their overall performance (Shankar and Mukherjee 2016). However, it can be noted that the concept of work compared to QOHSA has a number of differences, but not disadvantages, which makes them ± equal in their field of work.

3. Discussion

According to researchers, the problem of environmental stability has become increasingly urgent in recent years, energy systems using renewable energy sources are becoming increasingly popular with energy companies. This is especially noticeable in rapidly developing countries, Europe, America and Asia. However, the operation of such systems may be limited due to the instability of renewable sources. One solution to this problem is autonomous hybrid power plants based on renewable and traditional energy sources. Such stations are able to provide electricity to remote regions, islands or other areas where other power systems are not available or are economically inefficient (Shaimurunov et al. 2023). They can significantly reduce the cost of transporting fuel and reduce toxic emissions into the environment. When choosing a technology for the operation of autonomous hybrid power plants, solar and wind energy are considered to be

the most effective, since they have low operating costs and emit practically no emissions of toxic substances to the environment (Ismayil-Zada 2022; Chernets et al. 2008). Furthermore, traditional sources of electricity such as gas or diesel fuel can be used as a backup source of energy if renewable energy sources cannot provide enough energy. However, it must be taken into account that hybrid power plants are more difficult to operate and require professional knowledge and experience for maintenance and management. In addition, the construction cost of hybrid power plants can be higher than for conventional power plants.

In this paper, a study was made of autonomous hybrid power plants, their operation, battery problems and load-frequency stabilization. In comparison with the studies of Sadykov et al. (2018), it was found that the problem of batteries is currently critical. There are ways to improve their operation and increase the life and capacity of batteries thanks to the passive balancing system; however, such a system is a rather expensive method and in existing hybrid power systems, its installation without government funding can be problematic and sometimes not expedient. This method of improving performance to some extent eliminates one of the advantages of autonomous hybrid power plants – their low cost. In the case of installing such a system on a new power plant, the batteries initially receive load stabilization and regulation of the charge and discharge of the batteries, which from the moment they are launched will help extend their service life. However, when installing a passive balancing system on batteries that have been in operation for some time, their service life will be extended for a relatively short period, which still forces them to be replaced in the near future.

The solution to the problem of installing a passive balancing system in a power system that is already in operation may be to replace some of the most "worn out" batteries. Thus, using the power system in Figure 1 as an example, as described above, some batteries can suffer more damage with use due to charge surges and discharge. It is proposed to replace the two batteries with the worst capacity out of the four and then install a passive balancing system. Thus, the remaining pair of batteries will increase their service life by about one and a half times, and new energy storage devices will immediately be controlled by the system. However, thanks to the same system, the number of battery replacements due to wear and tear is reduced, which complements another plus of hybrid power plants – their environmental friendliness (Alameri and Alkaabi 2018). In the work of the World Health Organization (Recycling used lead-acid batteries 2017), the issue of the environmental friendliness of lead-acid batteries, and the problem of their disposal and so on have been studied. Research conducted by Cao et al. (2015) states that in areas where modern batteries are manufactured, abnormal levels of lead (Pb) in the blood of 12.45 μg dL^{-1} are found in children. Soil, dust, water bodies and food are heavily contaminated with target metals (loids). Of the total exposure to target metals, 80% comes from contaminated food. In children, non-cancer risks exceeded the allowable level of 1, 3–10 times, and the risk of cancer exceeded the maximum allowable level of 1.0×10^{-4} by 5–200 times. With the help of this data, it is possible to conclude that the use of rechargeable batteries, and their more frequent replacement on an industrial scale would only aggravate the environmental situation, from which it is possible to draw a simple conclusion: the less frequently the batteries are changed, the more environmentally friendly the energy system.

In their study, Dykes et al. (2020) described autonomous hybrid power plants, the principles of their operation, features, and the feasibility of installation, using the example of the United States of America. America's renewable energy potential is quite large as a result of the country's large area, landscape diversity, temperatures and, in particular, the presence of the west and east coasts bordering the Pacific and Atlantic oceans respectively, which create a huge potential for hydroelectric power in the country (Avdieieva et al. 2020). This article explores hybrid power plants using the example of Kyrgyzstan, which does not have such a vast area of territory and coasts bordering the ocean; however, for such a small country, Kyrgyzstan has a huge potential for renewable energy. This is particularly due to its mountainous terrain, rivers, mountain flows, winds and relatively stable year-round solar radiation radiated to the territory of the state, all of which makes it an excellent place for alternative energy. Kyrgyzstan has great potential for off-grid hybrid power plants, solar and wind energy, as Suyundukov and Sadykov (2020) highlight in their works. Additionally, taking into account the mountainous terrain of the country, its agricultural type and the fact that most farms and villages are located in places that are remote from large settlements, it can be concluded that autonomous hybrid energy is the best solution to the issue of supplying electricity to remote regions. The development of hybrid power plants based on different energy sources will contribute to the relatively inexpensive and rapid development of the infrastructure and economy of Kyrgyzstan.

The quasi-oppositional harmonization system based on the development of the frequency controller will improve the stability of the hybrid power system with several alternative energy sources, one backup energy source based on conventional sources (diesel or gas piston generator) and a multi-battery system (Havrysh et al. 2019). The issue of developing a load frequency stabilization system is currently being raised increasingly often among people studying or working with hybrid power plants. In recent years, more and more systems have appeared, including the harmony search system. In the scientific work of Shankar and Mukherjee (2016) such methods as QOBL (quasi-oppositional learning method), HSA (metaheuristic algorithm for quickly finding the effective area of decision vectors), TLBOA (learning-based harmony search method), as well as the QOHSA method discussed in the current article, based on QOBL and HSA methods are studied. These methods help to stabilize the frequency of the load in the hybrid power system during the switch between alternative energy sources and the generator (in case the solar panels and wind turbines do not produce enough power).

To sum up, it can be noted that autonomous hybrid power plants based on traditional and renewable energy sources are an excellent solution for supplying electricity to remote regions of Kyrgyzstan, and its renewable energy potential makes it easy to implement this idea. However, autonomous hybrid power plants have a critical problem in the form of batteries and their wear, as well as the less critical but still problematic stabilization of load frequency.

Conclusions

Based on the study of this topic, it can be concluded that autonomous hybrid power plants based on traditional and renewable sources of electricity are the best solution to the problems of ecology and the stability of the supply of electricity, in comparison with power plants based exclusively on traditional or renewable resources. Such solutions are also useful in the case of problems with the supply of electricity to remote settlements and regions where the placement of other energy systems is economically unprofitable. In the case of Kyrgyzstan, such power plants can be an ideal solution to the problem of the supply of electricity to remote villages and farms from both an environmental and economic point of view. The specific landscape of the country and its geographical location contribute to the presence of a huge renewable energy potential. Particularly useful are solar and wind energy, which are ideal for use in off-grid hybrid installations due to their low operating costs and the almost complete absence of toxic emissions into the environment. The problem of stand-alone hybrid power plants associated with the wear of rechargeable (in this study, 12-volt lead-acid) batteries is to some extent solved with the help of a passive balancing system that equalizes the voltage on each battery from the beginning of their charge, constantly monitoring the entire energy storage system and allowing the inclusion of new batteries in an already working system. This reduces battery wear and tear, extends battery life and, with fewer battery changes, makes the overall system cheaper and more environmentally friendly.

The QOHSA quasi-oppositional harmonization method stabilizes the load frequency of the power system during the switch from renewable sources to diesel/gas generators and compared to the TLBOA learning-based system, QOHSA is a more modern and reliable problem-solving method. This is as a result of the combination of the QOBL quasi-oppositional learning method and the algorithm for finding the best solution vectors HSA. The methods discussed in this article to improve the operation of autonomous hybrid power plants are excellent solutions to current problems. However, this study cannot be relevant for more than a couple of years due to the rapid development of technologies in this area. Due to this, over the next decade, Kyrgyzstan can completely switch to hybrid power plants or power plants based on exclusively renewable sources.

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Autonomiczne elektrownie hybrydowe oparte na odnawialnych i tradycyjnych źródłach energii elektrycznej

Streszczenie

Celem niniejszego artykułu jest rozważenie pasywnego systemu równoważenia akumulatorów, który w przyszłości zwiększy ich niezawodność, zmniejszy koszty konserwacji, zmniejszy zużycie i wydłuży żywotność, a także zbadanie nowej metody quasi-opozycyjnego poszukiwania harmonii w celu stabilizacji dostarczanej energii elektrycznej. W tym celu zastosowano różne teoretyczne metody badań naukowych (analiza, konkretyzacja, porównanie, uogólnienie). Rozważana w tym artykule metoda poprawy wydajności akumulatorów przy użyciu pasywnego systemu równoważenia, na przykładzie przedstawionego tutaj typowego schematu strukturalnego autonomicznej elektrowni hybrydowej, zwiększyłaby efektywność prac przedprojektowych nad opracowaniem wysoce wydajnych rozwiązań projektowych i obwodowych oraz wydłużyłaby żywotność baterii. Nowa metoda quasi-opozycyjnego poszukiwania harmonii dla hybrydowych elektrowni opartych na odnawialnych i tradycyjnych źródłach energii, z uwzględnieniem i tradycyjnych źródeł energii, biorąc pod uwagę cechy ich konstrukcji i działania, umożliwiłaby stabilizację częstotliwości obciążenia odbiorcy w momencie przełączania stacji pomiędzy źródłami zasilania. Niniejsze opracowanie może być przydatne dla środowiska osób związanych z energetyką, dla studentów studiujących energetykę odnawialną na uczelniach wyższych, a także dla ich wykładowców i ich nauczycieli, w celu zapoznania się z problemami stacji hybrydowych i znalezienia możliwości ich rozwiązania.

Słowa kluczowe: elektrownia, zasoby niewyczerpalne, baterie, częstotliwość obciążenia,
    układ bilansujący