Energy complexes based on small hydropower plants of factory readiness

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Abstract. This article covers the role and potential of small hydroelectric power plants (SHPP's) of factory readiness as part of the energy complex in the context of sustainable development of energy infrastructure and environmental safety. Attention is paid to the capabilities of the SHPP, as a key element in the strategies of reliable and environmentally friendly energy supply, especially in remote, decentralized and hard-to-reach areas. The SHPP effectiveness study requires an integrated approach covering the analysis of technological and environmental aspects. The article presents the results of the analysis of the SHPP projects implemented, emphasizing their contribution to the development of sustainable energy and highlighting both the advantages and challenges faced by these projects. The conclusion summarizes the results that indicate the importance of the SHPP as a tool for achieving the goals of renewable energy and sustainable development of the electric power industry as a whole.

1 Introduction

In today's world, where issues of sustainable development and environmental safety are becoming more urgent, attention to renewable energy sources is increasing significantly. Small hydroelectric power plants (SHPP) of factory readiness are one of the most promising areas in this area. These facilities can become key elements in strategies to ensure reliable, cost-effective and environmentally friendly energy supply, especially in remote, decentralized and hard-to-reach areas.

The SHPP under consideration have a high degree of factory readiness, which makes it possible to reduce the time and cost of their construction and installation, as well as simplify the process of transportation and commissioning. In addition, such stations can have minimal environmental impact, preserving natural landscapes and ecosystems.

However, the development of small hydroelectric power plants is not devoid of difficulties. The issues of choosing the optimal construction sites, assessing the potential impact on ecosystems, as well as integration into existing energy systems require an integrated approach and careful analysis [1].

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Thus, the relevance of this topic for modern energy is due to the ability to ensure environmentally friendly and cost-effective generation of electricity, opening up new opportunities for sustainable development of different regions [2].

2 Materials and methods

The purpose of this work is to analyze and evaluate the efficiency of using the power complex based on the SHPP of factory readiness. Energy complexes based on renewable energy sources can operate in large combined and isolated energy systems (network energy complexes), can be distributed generation facilities, as well as autonomous generating facilities operating as part of single-component energy systems [3-4].

As an example, the option of parallel operation of the SHPP with diesel power plants and other generators based on renewable energy sources was considered.

To ensure a seasonal guarantee of the SHPP, it is necessary to build reservoirs, otherwise, with a sudden decrease in the flow of the river, such as periods of drought or low water, it may be necessary to connect a backup diesel generator (DG) to prevent a power outage. In cases where the river freezes or its flow greatly decreases, DG becomes the main source of power (Figure 1) [5].

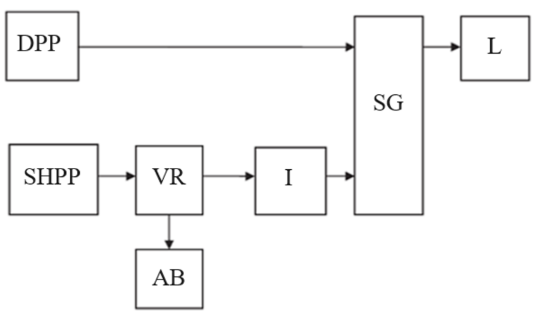

Fig. 1. Scheme of parallel operation of the SHPP and the DPP.

Figure 1 shows two power supply sources: the SHPP and the DPP. It is possible to recharge the accumulator battery (AB) as an emergency power source by rectifying the voltage to recharge it (VR); it is also possible to install an inverter (I) stabilizing the voltage of the unstable frequency. The energy of both sources is supplied to the switchgear (SG) and distributed to the load (L).

The option of recharging the batteries from both sources is shown in Figure 2 [5].

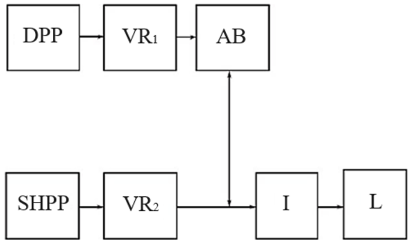

Fig. 2. Diagram with AB charging from the DPP.

The use of static frequency converters makes it possible to build hybrid power complexes providing for the joint operation of the SHPP and the DPP, as well as increasing the total power of such a local power supply system.

Also, the efficiency of RES use can be increased due to the use of combined energy complexes with several types of RES. In this case, the requirement of uninterrupted power supply is met with the variable nature of solar panel insolation (or the absence of wind when used in the wind power plant scheme) using buffer energy storage, the introduction of generating devices using wind, solar energy, water flows, diesel generators, etc. into the combined complex.

In the basic block diagram of the autonomous power supply system (Figure 3), the main power sources can be either the SHPP (within the guaranteed power) or the DPP. The solar battery (SB) is used to recharge the battery, but at a certain power, the SB can participate in the general power supply scheme. In this power supply scheme, at the full speed of the river, the main source of energy will be the SHPP, which means that the DPP can be turned off. The SB either participates in recharging AB or adds energy to the consumer together with the SHPP. Electric power from the SHPP or the DPP is supplied to the matching unit and distributed between the load control unit (LCU), rectifier (R), with further supply to the charging monitoring and control unit. The inverter converts the excess energy for transmission to the consumer.

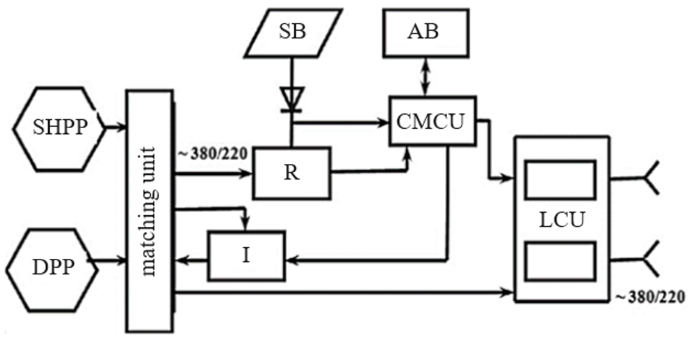

Fig. 3. Block diagram of power supply system from several power sources.

The study of the efficiency and capabilities of the power complex based on the SHPP of factory readiness requires an integrated approach, including the analysis of various aspects - from technological to environmental. Next, the methods and materials used to assess the potential of the SHPP as part of the power complex, as well as the key stages of the design and construction of such facilities, are considered.

Assessing location potential is the first and one of the most important steps. It includes analysis of hydrological data, assessment of the availability of water resources and potential environmental impact. Various geological and environmental studies are used, as well as modeling of water flows to determine the optimal power of the plant, depending on the composition of the energy complex, wind rose analysis may also be required for wind farms, etc.

The design of the SHPP involves the selection of the type of turbines, the development of a control and automation system, as well as infrastructure planning to ensure maximum efficiency and minimal impact on the ecosystem. This process takes into account technical innovations and best practices in the field of renewable energy.

The construction and installation of the SHPP of factory readiness is carried out using modular technologies that minimize the need for large-scale construction work on site and speed up the commissioning of the facility. This phase also includes measures to reduce environmental impact.

Monitoring and control of the SHPP after commissioning includes monitoring of operations, assessment of efficiency and environmental impact. Modern control and automation systems make it possible to optimize the operation of the SHPP, taking into account changes in water flows and power consumption. With proper operation and timely maintenance of the SHPP, the service life of the equipment can be increased by 1.5 times.

3 Results

The analysis of projects of energy complexes with the SHPP as part [6-9] revealed a number of key results that emphasize their contribution to the development of sustainable energy.

Efficiency and reliability: the SHPP demonstrate high energy conversion efficiency thanks to modern technologies and equipment. Their operation has shown reliability in various climatic and hydrological conditions, ensuring stable electricity generation, which is especially important for autonomous regions.

Environmental compatibility: Due to the use of advanced technologies and careful planning, MHPPs have a minimal impact on the environment. Measures to protect ecosystems, such as preserving natural vegetation around water bodies, contribute to maintaining biodiversity.

Socio-economic contribution: The implementation of the SHPP projects contributes to the development of local communities, improving access to energy in remote and hard-to-reach areas. In addition, the SHPP can become part of integrated solutions for the development of agricultural production, fishing and tourism.

Integration into the energy system: the SHPP have proven its ability to integrate effectively into existing energy systems, complementing other sources of renewable energy and contributing to their reliability and sustainability, or being the main source of energy.

More detailed results require further study, but at the moment it can be concluded that that if the SHPP is properly used factory ready, which implies the choice of the optimal guaranteed SHPP power, based on flooding, costs and other terrain features, together with other energy sources, the reliability of electricity supply can be improved, as well as reduce the negative impact on the environment in remote and decentralized areas. These results demonstrate the significant potential of the SHPP of factory readiness as a key element in the sustainable development of energy infrastructure.

4 Discussion

Discussion of the results of the study of power complexes based on the SHPP of factory readiness revealed not only their potential and advantages, but also some difficulties and disadvantages faced by these projects were highlighted.

The clear advantages include:

- The SHPP contribute significantly to the achievement of the sustainable development goals of the electric power industry, providing clean energy and helping to reduce dependence on fossil fuels.
- The SHPP provide a reliable source of energy for remote, decentralized and sparsely populated areas, where the construction of large energy facilities is economically impractical or impossible for other reasons [10].

- Modern equipment for the SHPP is characterized by full automation, high reliability and full operating life for at least 50 years. In the long term, the SHPP demonstrate high economic efficiency due to low operating costs and long service life.
- The disadvantages, in turn, include:
- Environmental risks, because despite the minimal impact on the environment, the construction and operation of the SHPP can negatively affect local aquatic ecosystems and biodiversity.
- High initial investment in design and construction can be an obstacle to the implementation of projects, especially in countries with limited resources, in which case additional support from the authorities is required for effective development in this direction.
- A complex permit and license process can slow down the development of the SHPP projects, requiring additional efforts to align with environmental and other regulations.

It is important to consider all these aspects when planning and implementing SHPP-based projects, aiming for a balance between energy needs and environmental conservation.

5 Conclusion

The study of energy complexes based on small factory-ready hydroelectric power plants allows us to conclude that these facilities have significant potential in the context of sustainable development and the transition to environmentally friendly energy sources [11]. The SHPP can play a key role in ensuring reliable and affordable energy supply, especially in remote and underdeveloped regions, contributing to socio-economic development and improving the quality of life of the population.

However, to realize the full potential of the SHPP, an integrated approach is needed, including the development and implementation of technological innovations, optimization of design and construction processes, as well as consideration of environmental and social factors. An important aspect is cooperation between public bodies, the private sector and local communities to create favorable conditions and incentives for the development of the SHPP projects.

Ensuring strict compliance with environmental standards and developing measures to minimize impacts on natural ecosystems and biodiversity is also critical. The implementation of these approaches will maximize the benefits of the SHPP, while reducing potential risks and negative consequences.

In conclusion, I would like to add that the SHPP of factory readiness are an important tool for achieving the goals in the field of renewable energy and sustainable development of the electric power industry as a whole. Their further development and integration into the energy system will require joint efforts of all stakeholders aimed at creating a bright energy future.

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