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АНАЛИЗ ПОКАЗАТЕЛЕЙ ЭНЕРГОЭФФЕКТИВНОСТИ СИСТЕМ СОЛНЕЧНОГО ЭЛЕКТРОСНАБЖЕНИЯ

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Аннотация. *В статье рассмотрены ключевые показатели энергоэффективности систем солнечного электроснабжения и их влияние на надёжность и экономическую эффективность. Показано, что повышение энергоэффективности способствует устойчивому функционированию энергетических систем.*

Ключевые слова: *солнечное электроснабжение, энергоэффективность, возобновляемые источники энергии, показатели эффективности, устойчивое развитие.*

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ANALYSIS OF ENERGY EFFICIENCY INDICATORS OF SOLAR POWER SUPPLY SYSTEMS

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Abstract. *The article examines key energy efficiency indicators of solar power supply systems and their impact on reliability and economic efficiency. The results show that improved energy efficiency enhances the sustainable operation of energy systems.*

Keywords: *solar power supply, energy efficiency, renewable energy, performance indicators, sustainability.*

Introduction

The rapid development of renewable energy technologies has significantly transformed modern power supply systems. Among renewable energy sources,

solar power occupies a leading position due to its environmental friendliness, scalability, and technological maturity. Solar power supply systems are widely used in residential, commercial, and industrial sectors, contributing to energy diversification and reduction of greenhouse gas emissions. However, the effectiveness of solar energy utilization largely depends on the energy efficiency of solar power systems. Energy efficiency indicators play a crucial role in evaluating system performance, determining economic feasibility, and ensuring sustainable operation. Low efficiency leads to increased capital and operational costs, while optimized efficiency enhances system reliability and return on investment. Therefore, analyzing energy efficiency indicators of solar power supply systems is an important scientific and practical task. This study focuses on identifying key indicators and assessing their influence on the overall performance of solar energy systems.

Methods and materials

The research is based on a comprehensive methodological approach combining technical and economic analysis. The following methods were applied:

- analysis of solar power system performance parameters;
- evaluation of energy efficiency indicators;
- comparison of different system configurations;
- assessment of economic and environmental impacts.

The object of the study is a typical photovoltaic (PV) power supply system consisting of solar panels, inverters, energy storage units, and auxiliary equipment. The analysis considers both grid-connected and standalone solar power systems operating under various climatic and load conditions. Energy efficiency indicators were calculated using standard engineering approaches and international recommendations for solar energy systems.

Energy efficiency indicators of solar power supply systems

Energy efficiency of solar power systems is characterized by a set of quantitative indicators reflecting the ability of the system to convert solar radiation into usable electrical energy. The main indicators include:

- Photovoltaic efficiency, which shows the ratio of electrical output to incident solar energy;
- Performance Ratio (PR), reflecting system losses and overall performance;
- Capacity Utilization Factor (CUF), indicating the actual energy output relative to the maximum possible output;
- System efficiency, accounting for inverter, wiring, and storage losses.

These indicators provide a comprehensive assessment of solar power system performance and allow identification of inefficiencies at different stages of energy conversion.

Factors affecting energy efficiency

Several factors influence the energy efficiency indicators of solar power supply systems:

- solar radiation intensity and climatic conditions;
- orientation and tilt angle of photovoltaic panels;
- quality and type of photovoltaic modules;
- inverter efficiency and control strategy;
- temperature effects and shading losses.

Improper system design or unfavorable operating conditions can significantly reduce efficiency. Therefore, optimization of system configuration and operating modes is essential to achieve high performance.

Economic aspects of energy efficiency improvement

Energy efficiency directly affects the economic performance of solar power supply systems. Higher efficiency leads to increased energy generation, reduced payback period, and improved investment attractiveness. Economic evaluation includes analysis of capital costs, operational expenses, energy savings, and lifecycle cost. Improving energy efficiency indicators reduces the levelized cost

of electricity (LCOE) and enhances competitiveness of solar energy compared to conventional power sources. In many cases, investments in efficiency improvements are economically justified with payback periods ranging from 3 to 7 years.

Environmental and sustainability impact

High energy efficiency of solar power systems contributes to environmental sustainability by reducing resource consumption and minimizing carbon emissions. Efficient systems require fewer photovoltaic panels and auxiliary components, lowering material usage and environmental footprint. Additionally, improved efficiency supports energy security and sustainable development goals by increasing the share of renewable energy in the power supply mix.

Discussion of results

The analysis shows that energy efficiency indicators are critical parameters determining the technical and economic success of solar power supply systems. Integrated optimization of system design, component selection, and operating conditions allows significant improvement in efficiency and overall performance. The results confirm that systematic evaluation of efficiency indicators should be an integral part of solar power system planning and operation.

Conclusion

This study analyzed the energy efficiency indicators of solar power supply systems and assessed their technical, economic, and environmental significance. It was established that improving efficiency indicators enhances system reliability, reduces energy costs, and increases economic sustainability. The findings can be used in the design, modernization, and evaluation of solar power supply systems in various applications.

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