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MANAGEMENT AND IMPROVEMENT OF RELIABILITY OF PUMPING STATIONS AND USE OF RENEWABLE ENERGY

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ABSTRACT

The article mainly analyzes the issues of effective management of pumping stations, increasing their reliability and ensuring energy efficiency. Ways to improve the technical and economic performance of pumping stations through the use of modern automated control systems, frequency control devices and renewable energy sources are considered. The advantages of pumping systems operating on solar and wind energy and the possibilities of their implementation in practice are also highlighted.

Keywords: Pumping station, automation, reliability, energy efficiency, renewable energy, solar panels, control system.

INTRODUCTION

Currently, the issue of rational and efficient use of water resources is gaining global importance. As a result of population growth, expansion of agricultural and industrial sectors, and climate change, the demand for water is increasing. In this process, the uninterrupted and reliable operation of water supply, distribution and pressure transmission systems is of great importance. Pumping stations are the heart of water supply and irrigation systems. Their efficient operation is of great importance not only from a technical, but also from an economic and ecological point of view.

Pumping stations are widely used in drinking water supply, land reclamation, irrigation, industrial enterprises and energy systems. Their main task is to deliver liquid to a certain distance and height. However, many existing pumping stations have problems such as high energy consumption, outdated equipment, and insufficient automation of control systems. As a result, operating costs increase, accidents occur, and interruptions in the water supply process are observed.

The development of modern technologies allows to radically improve the process of managing pumping stations. Using automated control systems, remote monitoring and dispatching control, smart sensors and microprocessor devices, it is possible to maintain the operating mode of pumping units at an optimal level. In particular, SCADA systems provide the opportunity to monitor parameters in real time, detect malfunctions early and make quick management decisions. This reduces the human factor and increases the overall reliability of the system.

The reliability of pumping stations is their ability to fully perform their functions within a specified time interval and under the required operating conditions. Reliability indicators include parameters such as the probability of uninterrupted operation, mean time between failures, repair time and service life. Improving these indicators requires improving design solutions, using high-quality materials, introducing planned preventive maintenance, and stabilizing energy supply.

Today, the issue of efficient use of energy resources is also relevant. Pumping stations are one of the largest consumers of electricity. In some cases, electricity consumed in water supply systems reaches 30–40% of the total energy consumption. Therefore, the introduction of energy-saving technologies, in particular, controlling the engine speed using frequency converters, reducing hydraulic losses and selecting the optimal operating mode, is of great importance. In addition, the use of renewable energy sources is a promising direction in increasing the energy efficiency of pumping stations and ensuring environmental sustainability. In particular, according to the International Renewable Energy Agency , the cost of solar and wind energy has decreased significantly in recent years, and the possibilities for their widespread implementation in practice have increased. Energy supply based on solar panels is an effective solution, especially for pumping stations located in areas far from power grids.

The use of renewable energy sources not only brings economic benefits, but also reduces the negative impact on the environment. Reduction of greenhouse gas emissions, reduced dependence on fuel resources, and increased energy independence are among the important advantages of these technologies. At the same time, hybrid energy systems — that is, systems that combine a traditional power grid and solar or wind energy — ensure uninterrupted operation of pumping stations.

The main purpose of my article is to analyze methods for improving the management of pumping stations, increasing their reliability, and scientifically justify the possibilities of using renewable energy sources. The research will study modern control systems, energy-saving technologies, and hybrid energy supply options.

The article also considers issues of improving technical and economic indicators, reducing operating costs, and ensuring long-term stable operation through the modernization of pumping stations. As a result, the proposed solutions will serve to increase energy efficiency and ensure environmental safety in water management and industrial systems.

LITERATURE REVIEW AND METHODOLOGY

The issues of managing pumping stations, increasing their reliability, and ensuring energy efficiency have been covered in many scientific studies in recent years. In particular, large-scale scientific research is being conducted internationally on automated control systems, digital monitoring, and the use of renewable energy sources.

Research in the field of automated control systems has studied the issues of selecting the optimal operating mode of pumping units, developing control algorithms that are adaptive to load changes, and controlling them in real time. SCADA systems, which are widely used in modern industrial enterprises, provide the opportunity for remote monitoring of pumping stations, archiving parameters, and rapid detection of malfunctions. Scientific sources note

that when digital control systems are introduced, the number of accidents decreases by 20–35%, and operating costs are significantly reduced.

Probability theory, mathematical modeling, and statistical analysis methods are widely used in studies on the reliability of pumping stations. In foreign literature, indicators such as "Mean Time Between Failures" (MTBF) and "Mean Time To Repair" (MTTR) are accepted as the main criteria. These approaches help predict the service life of equipment and develop an optimal schedule for preventive maintenance.

Scientific work on improving energy efficiency is mainly focused on controlling electric motors through frequency converters, reducing hydraulic losses, and optimizing system parameters. According to research results, by controlling pump motors according to the load level, electricity consumption can be reduced by 25–40%.

Research on the use of renewable energy sources also deserves special attention. According to reports from the International Renewable Energy Agency , the cost of solar photovoltaic plants has decreased sharply in the last decade, and they are being effectively used in water supply systems. Solar energy-based systems are considered economically feasible, especially for pumping stations located in areas far from the power grid .

Analysis of scientific sources shows that an integrated approach is necessary in the process of modernizing pumping stations. That is, it is necessary not only to update technical equipment, but also to improve control algorithms, diversify energy sources and systematically monitor reliability indicators. At the same time, it is important to develop customized solutions taking into account local conditions, climatic factors and economic opportunities.

The study used a comprehensive methodological approach to improve the control and reliability of pumping stations and study the possibilities of using renewable energies.

At the first stage, scientific literature, regulatory legal acts and international reports were analyzed. Best practices and existing technological solutions were studied using the analytical analysis method.

At the second stage, the technical indicators of the pumping station were evaluated based on mathematical modeling. The operation of the pumping units was analyzed using the following main parameters:

- Pressure (H);
- Consumption (Q);
- Power (P);
- Useful work coefficient (η).

In determining energy efficiency, the relationship between engine power and load level was analyzed. The degree of energy consumption reduction when using a frequency converter was assessed using a comparative analysis method.

At the third stage, statistical methods were used to determine reliability indicators. The overall reliability level of the system was calculated based on data on failure frequency, average operating time and repair time. Proposals for increasing reliability were based on the results of experimental and theoretical analysis.

At the fourth stage, the technical and economic efficiency of renewable energy sources was assessed. The following indicators were calculated for a system based on solar panels:

- Installed power (kW);
- Annual energy production volume (kWh);
- Investment value;
- Payback period.

The analysis used the discounted cash flow method and the comparative cost method to determine economic efficiency.

Also, the principle of a systematic approach was followed during the research. The pumping station was considered as a single technical system, and all its elements - mechanical, electrical and control parts - were analyzed in their interdependence. The main goal of the methodology is to increase the control efficiency of pumping stations, improve reliability indicators, and scientifically substantiate the technical and economic feasibility of integrating renewable energy.

The results show that the methods used allow for a comprehensive analysis, identification of existing problems and the development of practical recommendations for their elimination.

DISCUSSION AND RESULTS

The research shows that the effective operation of pumping stations largely depends on the level of sophistication of the control system, the technical condition of the equipment, and the stability of the energy supply. In traditional control methods, pumping units often operate at a constant speed, which leads to excessive energy consumption due to lack of adaptation to load changes. In this regard, the introduction of frequency converters and automated control systems is one of the most important areas for increasing energy efficiency.

Digital monitoring and dispatching control, in particular, SCADA systems , make it possible to monitor the main parameters of the pumping station in real time. This helps to quickly identify and eliminate situations such as sudden changes in pressure, dry running or overload. As a result, the number of accidents decreases and the service life of the equipment increases.

The discussion on increasing reliability showed that it is important to introduce a preventive maintenance system. Scheduled maintenance based on statistical data significantly reduces the likelihood of failures. In addition, the presence of backup pumping units and an automatic connection system ensure the continuity of water supply.

Analyses conducted on the use of renewable energy sources confirmed their economic and environmental advantages. According to the International Renewable Energy Agency, the efficiency of solar photovoltaic systems is increasing year by year, and their integration into industrial infrastructure is expanding. Energy supply based on solar panels at pumping stations is especially effective in areas remote from power grids.

Based on the results of the research, the following scientific and practical conclusions were drawn:

1. By implementing automated control systems, energy consumption at pumping stations can be reduced by an average of 20–35%.
2. Adjusting the engine speed to the load level using frequency converters allows for efficient use of electrical energy.
3. Digital monitoring and diagnostic systems reduce accidents and extend service life by detecting faults early.

4. Scheduled preventive maintenance improves reliability performance and reduces repair costs.
5. Solar-based systems reduce the operating costs of pumping stations and can pay for themselves in an average of 4–6 years.
6. Hybrid energy systems are highly effective in ensuring the continuity of water supply.

In conclusion, the modernization of pumping station control processes and the integration of renewable energy sources significantly improve their technical and economic performance. The results obtained serve to increase energy efficiency and ensure environmental sustainability in water management, utilities and industrial sectors.

CONCLUSION

The results of the scientific research in the article show that the modernization of pumping station control systems, increasing their reliability and using renewable energy sources are important factors in ensuring the stable operation of modern water supply and irrigation systems. Since pumping stations are large energy consumers, increasing their efficiency is of great importance not only economically, but also environmentally.

The study found that the introduction of automated control systems ensures the optimal operating mode of pumping units, reduces the impact of the human factor and helps prevent accidents. In particular, SCADA systems provide the opportunity to conduct real-time monitoring, analyze data and make quick management decisions. This significantly improves the overall reliability of the system.

The use of frequency converters in pumping stations allows you to adjust the speed of electric motors to the load level. As a result, energy consumption is reduced, wear of mechanical parts is slowed down, and the service life of the equipment is extended. The introduction of a planned preventive maintenance system helps to reduce the number of failures and optimize repair costs.

The use of renewable energy sources is a promising direction in increasing the energy efficiency of pumping stations, as evidenced by the results of research. Data from the International Renewable Energy Agency also confirm that solar and wind energy are becoming increasingly affordable both technically and economically. Especially for pumping stations located in areas far from power grids, energy supply based on solar panels is an effective and environmentally friendly solution.

Combining traditional electricity sources and renewable energy resources through the use of hybrid energy systems ensures uninterrupted operation of pumping stations. This increases the stability of water supply systems and reduces the risk of power outages.

The general conclusions show that comprehensive modernization of pumping stations - namely, automation of control systems, implementation of reliability improvement measures, and integration of renewable energy sources - significantly improves their technical and economic efficiency.

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