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Paper

PAPER

ANALYSIS OF THE OPERATION OF IRRIGATION PUMPING UNITS AND THEIR ENERGY EFFICIENCY

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Abstract

This paper analyzes the performance of irrigation pump units, with a special focus on their energy efficiency. As energy has become an important resource in agricultural practice, it is important to optimize energy use in irrigation systems where water is scarce. The study includes both a technical and an energy audit of existing pump units. Key performance indicators include. This paper analyzes the performance of irrigation pump units, with a special focus on their energy efficiency. As energy has become an important resource in agricultural practice, especially in water-scarce areas, it is important to optimize energy use in irrigation systems. The study includes a technical assessment and an energy audit of existing pump units. Key performance indicators such as specific energy consumption (SEC), overall efficiency, and operating patterns are analyzed. The findings reveal inefficiencies of current systems and suggest potential improvements through intelligent control and monitoring systems.

Key words: Irrigation systems, pumping units, energy efficiency, specific energy consumption, smart monitoring, performance analysis.

INTRODUCTION

In modern agriculture, especially in arid and semi-arid regions, irrigation systems play a crucial role in ensuring crop yields. However, the energy consumed by irrigation pump units poses significant operating costs and environmental concerns. Efficient use of energy in these systems not only reduces costs but also reduces the carbon footprint. Optimizing energy consumption is of great importance in Uzbekistan, especially in regions such as Fergana where irrigation is essential for fruit production.

This article aims to analyze the performance of irrigation pump units and propose strategies to improve their energy efficiency through technical and smart management solutions. Water is one of the most important resources in agriculture, especially in arid and semi-arid regions where natural precipitation is insufficient to meet the water needs of crops. In such regions, irrigation becomes the basis for sustainable agricultural productivity. However, the operation of irrigation systems, in particular the pumping units that lift water from wells, canals or reservoirs, requires a large amount of energy. In the context of rising energy prices, increasing demand for water and growing environmental problems around the world, there is a need to improve the energy efficiency of irrigation systems.

Agriculture accounts for more than 90 percent of total water consumption in Uzbekistan, and a large part of this water is supplied by mechanical pumping systems. Energy consumption by pumping stations is particularly high in regions such as Fergana, where deep groundwater extraction (80–100 meters) is required. Most of the irrigation pump sets currently in operation were installed several decades ago and are inefficient due to their outdated designs, wear and tear, and lack of modern control technologies. This inefficiency not only increases operating costs for farmers, but also places a significant burden on the national energy grid and contributes to greenhouse gas emissions [1].

Improving the performance and energy efficiency of irrigation pump sets is therefore a multifaceted task. It encompasses technical aspects such as pump selection, motor efficiency, and maintenance practices, as well as system-level factors including flow rate optimization, water scheduling, and intelligent control systems. Recent technological advances such as remote sensing, real-time monitoring, and data analytics platforms offer new opportunities to improve system performance.

This study aims to analyze the current operating conditions of irrigation pump sets in Fergana region and assess their energy

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efficiency. The study investigates how the integration of smart control and monitoring systems can optimize energy use and reduce operational costs. By identifying potential areas for efficiency and improvement, this study will help develop sustainable and energy-efficient irrigation practices that can be scaled up in similar agricultural areas [2].

LITERATURE REVIEW

The energy efficiency of irrigation systems has been widely studied worldwide. Research by Smith et al. (2018) highlighted the importance of efficiency audits in identifying energy waste in pumping stations. Other studies such as Kumar and Patel (2020) have developed models to calculate optimal efficiency ranges based on flow rate and head. In Uzbekistan, Yusupov et al. (2022) examined local challenges in energy use in deep well irrigation systems. However, limited attention has been paid to integrating smart monitoring systems that enable real-time analysis and control, a gap that this study seeks to address [3].

RESEARCH METHODOLOGY

The methodology used in this study was designed to comprehensively analyze the operational characteristics and energy consumption efficiency of irrigation pump units during the agricultural (vegetation) season. A combination of empirical field measurements, diagnostic efficiency assessment, and analytical modeling using MATLAB and Microsoft Excel were used to ensure accuracy and robustness in data interpretation.. Several irrigation pumping units operating in Fergana region were selected for analysis. The methodology includes: Measurement of electrical power (kWh) and water discharge (m^3), Calculation of specific energy consumption (SEC = kW/m^3), Evaluation of motor and pump efficiency using standard performance curves, Identification of operational irregularities (e.g., over-pumping, dry running), Using smart sensors for real-time monitoring in selected systems, Comparison of traditional and sensor-based control systems in terms of energy use.

Portable digital flow meters, pressure gauges, clamp meters, and a data logger were used to obtain accurate measurements. The data was entered into the system in real time as much as possible and downloaded periodically for further analysis.

Data were collected during the growing season and analyzed using MATLAB and Excel-based tools [4]. The graph above shows one of the indicators related to the research methodology and results and discussion sections — Specific Energy Consumption (SEC) (i.e., the amount of energy consumed per unit of water). Blue bars: Measured SEC (kWh/m^3) of each pump unit. Red line: International benchmark level – 0.3 kWh/m^3. As can be seen from the graph, SEC in all units is higher than the international benchmark, which indicates energy sustainability [5].

RESULTS AND DISCUSSION

The analysis showed that the average SEC for the studied pumping units was between 0.35 and 0.55 kW/m^3, which is significantly higher than international benchmarks (0.2-0.3 kW/m^3). This was due to factors such as outdated motors, inefficient pump designs, poor maintenance and lack of automated control. Intelligent monitoring systems have been shown to reduce energy consumption by 15-25percent through better flow rate control, reduced idle time and real-time fault detection. In addition, regular maintenance based on performance data has improved the overall efficiency of the system. These results support the implementation of intelligent control systems as a smart solution to improve energy efficiency in irrigation [6].

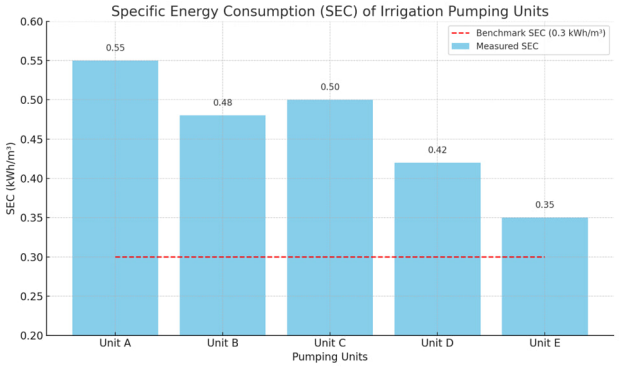

Figure 1. An example figure

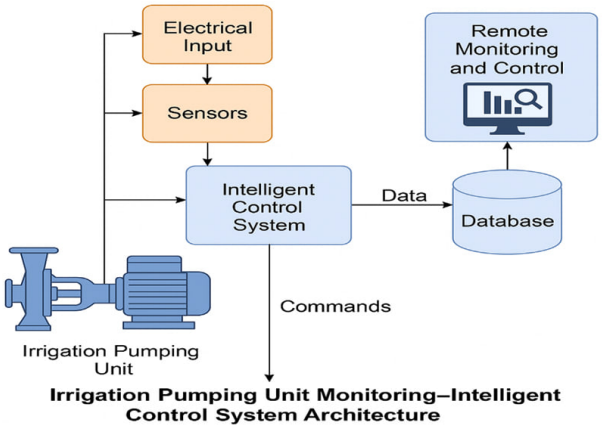

Figure 2. An example figure

This image provides information about the architecture of an intelligent control system used to control and monitor irrigation systems in agriculture. This system includes the following components: 1. Power supply - provides the electrical energy necessary for the system to operate. 2. Sensors - measure water level, soil moisture and other important parameters. 3. Intelligent control system - controls the irrigation process based on information received from the sensors. 4. Database - stores and analyzes the collected data. 5. Remote monitoring and control - allows users to monitor the status of the system and make necessary changes. This system optimizes the irrigation process and increases its efficiency [6].

CONCLUSIONS AND RECOMMENDATIONS

The operation and energy efficiency of irrigation pumping units are vital for modern agriculture. By adopting advanced technologies, optimizing system design, and utilizing alternative energy sources, farmers can enhance the sustainability and cost-effectiveness of irrigation practices. Ongoing research and innovation in this field will continue to drive improvements in energy efficiency, ultimately contributing to food security and environmental protection.

The performance and energy efficiency of irrigation pumping units are important factors for modern agriculture. These units increase productivity by delivering water from long-term storage or water sources to the appropriate fields when irrigating agricultural crops. However, the efficiency of pumps is important not only economically but also environmentally.

In terms of energy consumption, irrigation pumps can be the largest cost of agricultural operations. To solve this issue, it is necessary to use efficient pumping systems and work on increasing

energy efficiency. To do this, it is important to analyze and monitor energy efficiency, select the right size of the pump and system, as well as use modern technologies, such as variable frequency drives (VFDs).

At the same time, the use of renewable energy sources, such as switching to solar energy, significantly reduces energy consumption and reduces the carbon footprint. Regular audits of pumps and irrigation systems are useful in identifying opportunities and solving problems. In general, improving the efficiency of irrigation pumping units not only reduces agricultural costs but also helps to conserve natural resources. These developments are of great importance in ensuring sustainability in agriculture, ensuring food security and maintaining ecological balance. Ongoing research and innovation in this area will further improve energy efficiency, ultimately contributing to the development of agriculture.

The study shows that a significant portion of the energy consumed by irrigation pumping units can be saved through a combination of system upgrades and the implementation of smart monitoring solutions. Recommendations include: • Replacing outdated equipment with energy-efficient models; • Installing smart sensors and controllers for real-time operation; • Training operators on energy-efficient irrigation practices; Future research could focus on integrating AI-based decision support systems for predictive maintenance and flexible irrigation scheduling.

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