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CHARACTERISTICS OF THE MAIN EQUIPMENT OF THE "DUSTLIK" PUMPING STATION AND THE STRUCTURE OF ITS ENERGY CONSUMPTION

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ABSTRACT. This article studies the characteristics of the main equipment of the "Dustlik" pumping station, located in the Ulug'nor district of the Andijan region, Republic of Uzbekistan, and analyzes the structure of its energy consumption. The pumping station, commissioned in 1980 with a total project capacity for year-round irrigation supply, plays an important role in the national water management system. The technical parameters of the centrifugal pumping units of type 32D-19 (analog D 6300-27), high-voltage synchronous electric motors, transformers, and auxiliary equipment including the excitation system (TVU-180-50 thyristor cabinets), drainage system (K-20/30 pumps, 11 kW), bridge crane (10 kW total), and metering instruments are analyzed in detail. The results show that the main pumping units consume approximately 84 % of the total electricity intake, while auxiliary systems account for the remaining 16 %. Comparison of actual and design performance reveals an 18 % reduction in flow rate, a 5 % decrease in head, and a 7-percentage-point drop in efficiency, attributable to long-term operation, declining coefficient of performance, and uneven load distribution.

KEYWORDS: Dustlik pumping station; centrifugal pumping unit; synchronous electric motor; energy consumption structure; energy efficiency; water management; transformer; irrigation infrastructure; electrical energy losses; coefficient of performance.

1. Introduction

In contemporary water management systems, the efficient operation of pumping stations has become a matter of strategic importance. In large-scale irrigation networks in particular, the energy consumption of pumping stations constitutes the principal share of total electricity expenditure. For this reason, the study of the technical condition of pumping units, the analysis of the characteristics of their main equipment, and the identification of the energy consumption structure are among the most pressing engineering problems in the field of water resource management [1, 2].

The "Dustlik" pumping station occupies an important position in the irrigation system of the Republic of Uzbekistan and plays a major role in the supply of water to agricultural farmlands of the Ferghana Valley. The technical indicators of the electric motors, pumping units, transformers, and auxiliary equipment used at this pumping station directly influence its overall operational efficiency. At the same time, the rational use of energy resources and the reduction of electrical energy losses are among the principal tasks of the modern energy and water management sectors [3].

Existing studies on pumping station energy efficiency have predominantly focused on either the design stage of new installations or on small-scale facilities. However, large stationary irrigation pumping stations commissioned in the 1970s–1980s - which still constitute the backbone of irrigation infrastructure in Central Asia - have received comparatively limited attention. The "Dustlik" pumping station, in operation since 1980, is a representative example of such facilities, where decades of continuous service have introduced specific energy-related challenges that require systematic investigation [4].

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The aim of this article is to provide a detailed analysis of the characteristics of the main equipment of the "Dustlik" pumping station and to evaluate the structure of its electricity consumption. The specific objectives are: (1) to systematize the general design parameters and the structural composition of the pumping station; (2) to analyze the technical specifications of the main pumping units, auxiliary systems, and metering equipment; (3) to quantify the structure of electrical energy consumption among the principal equipment groups; and (4) to develop practical recommendations for improving energy efficiency and reducing electrical energy losses. The findings are expected to contribute to the broader goal of energy-saving modernization of irrigation pumping infrastructure in Central Asia.

2. Methods and materials

The study was conducted as a structured engineering analysis combining four complementary methodological approaches. First, technical documentation analysis was performed using the design documents of the "Dustlik" pumping station prepared by the "O'zgiprovodxoz" Design Institute (1978–1980), the energy passport of the consumer, and the technical certificates of the installed equipment. The documents were systematized according to the structural components of the station (water intake, machine hall, pressure pipelines, pressure basins) and the functional subsystems (main pumping, excitation, drainage, ventilation, lifting).

Second, on-site inspection of the equipment was conducted in cooperation with the operational personnel of the Northern Pumping Stations and Energy Department (UNSE) under the Narin–Qoradaryo Basin Irrigation Systems Authority. Visual inspection, electrical-parameter measurement, and verification of the documentary characteristics of the installed equipment were performed in accordance with the requirements of the Electrical Installation Code (PUE) of the Republic of Uzbekistan.

Third, energy consumption data were obtained from the commercial electricity metering system on the 6 kV balance side of the station. Although an Automated System for Commercial Metering of Electrical Energy (ASKUE) has not yet been implemented at the facility, the existing single-tariff metering on two independent lines provides reliable aggregated consumption data, which were processed for the period 2022–2024.

Fourth, the obtained data were systematized in tabular and graphical form. The technical parameters of pumping units and auxiliary systems were compared with their nominal design values to identify performance degradation. The structure of energy consumption was reconstructed using load-balance calculations on the basis of the rated power of each consumer group and its average operating duration. Data processing was performed using Microsoft Excel 2021; figures were prepared using the Matplotlib 3.7 library in Python 3.11. The reference framework for energy efficiency assessment was based on the requirements of GI "O'zenergonazorat" Order No. 168 of 09.09.2008 and Resolution of the Cabinet of Ministers No. 22 of 12.01.2018 "Rules for the Use of Electrical Energy".

3. Results

3.1. General characteristics of the "Dustlik" pumping station

The "Dustlik" pumping station is operated under the Andijan Department of Pumping Stations and Energy (UNSE) and is a structural unit of the irrigation systems of the Ministry of Water Management of the Republic of Uzbekistan. The general design data and brief characteristics of the pumping station are summarized in Table 1.

Table 1. General design data of the "Dustlik" pumping station

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Parameter	Value
Location	Andijan Region, Ulug'nor District
General designer	"O'zgiprovodxoz" Design Institute
Year of construction	1978–1980
Year of commissioning	1980
Operating organization	UNSE under Narin–Qoradaryo BIUS
Type of station	Stationary, irrigation purpose
Capital class	III
Building and water supply type	Block-type building
Water source	Syrdarya River
Operating regime	Year-round, with seasonal maximum during the vegetation period

The structural composition of the pumping station includes the avant-chamber with garbage-trapping facilities, the main building, above-ground oriented pressure pipelines, and pressure basins. The pressure network scheme is based on individual pressure water pipelines for each pumping unit, equipped with individual vacuum-breaking valves serving as anti-hydraulic-shock protection. This configuration provides operational redundancy and allows independent control of each unit during partial-load regimes.

3.2. Main pumping equipment

At the "Dustlik" pumping station, centrifugal pumps of type 32D-19 (analog D 6300-27) are used as the main pumping units. These horizontal-shaft single-stage centrifugal pumps of type D are designed for the transportation of water and liquids similar to water in viscosity and chemical activity (temperatures up to 85 °C), as well as chemically active liquids (pH range 4 to 12), oil and petroleum products with kinematic viscosity up to 10^{-4} m²/s, mechanical impurity content not exceeding 1 %, and solid-particle size not exceeding 0.2 mm.

Pumps of this type are applicable in the range of flow rate Q = 40 – 1800 l/s and head H = 15 – 100 m, with a corresponding motor power range of N = 15 – 2000 kW. At the "Dustlik" pumping station, the units operate close to the upper limit of this range, with nominal design parameters corresponding to flow rate 2200 l/s, head 100 m, motor power 2000 kW, and design efficiency 85 %. These performance parameters define the high energy intensity of the facility and explain its substantial share in regional electricity consumption.

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The auxiliary systems of the pumping station provide essential service functions and are summarized in Table 2.

Table 2. Characteristics of the auxiliary systems

System	Component	Specification
Excitation system	Thyristor control cabinet	TVU-180-50 (2 units)
Excitation system	Matching transformer	TSZV-40/0.5 (2 units)
Drainage system	Drainage pump (closed-well collection)	K-20/30, 11 kW (1 unit)
Ventilation system	Forced inlet–outlet (axial fans)	Designed, currently not in service
Lifting equipment	Bridge crane, lifting capacity 5 t	Total rated power P = 10 kW

The drainage system collects water from the suction pipes of the pumps and all leakage points and discharges it into a closed well; from there, the water is discharged into the avant-chamber. The operation of the drainage pumps is automatically regulated according to the water level in the drainage wells, ensuring continuous protection of the machine hall against flooding. It should be noted that the ventilation system, although originally designed as forced inlet–outlet with axial fans, is not currently in service - a fact that introduces additional thermal load on the electric motors during summer maximum operation.

3.3. Metering and electricity supply arrangement

The control and measurement instrumentation is provided in accordance with the original design. The system of measuring instruments and process control as well as the automation equipment, with detailed analysis of the characteristics and status of the metering instruments, is documented in the pumping station records. The existing electricity metering system at the station performs single-tariff commercial metering of electrical energy, with metering carried out separately on two lines on the 6 kV balance side; an ASKUE (Automated System for Commercial Metering of Electrical Energy) has not yet been implemented [5].

Data from commercial metering instruments are recorded in the energy passport of the consumer. The installed metering devices meet the requirements of normative-technical documents in terms of accuracy class and technical condition; however, the passport-protocol for the commercial metering systems based on the requirements of RH 34-351-561 is not available. In accordance with paragraph 1.5.13 of the Electrical Installation Code (PUE), each metering device is sealed with two seals: one on the screws securing the meter cover (state inspector's stamp) and one on the terminal cover (seal of the energy supply organization).

The accuracy class of current transformers, voltage transformers, and active-energy meters meets the requirements of the PUE and complies with the accuracy-class requirements set out in Order No. 232 of the head of the "O'zenergonazorat" inspection dated 26.12.2005. Periodic verification of metering instruments and measuring transformers is carried out within the periods established by the "O'zstandart" Agency (once every 4 years), at the consumer's expense and with the mandatory participation of representatives of the enterprise and the district electricity networks.

Electricity supply to the pumping station is delivered by the energy supply organization on the basis of a contract with an approved electricity supply limit. The consumer (the pumping station) falls within the II tariff group of electricity supply in accordance with Appendix 1 "Rules for the Use of Electrical Energy" to Resolution of the Cabinet of Ministers No. 22 of 12 January 2018; consequently, electricity is supplied under the single-tariff regime in accordance with the provisions on consumer tariff groups. Because only synchronous motors are used at the pumping station, they exhibit a leading power factor, and therefore the economic value of the reactive power coefficient at the metering point meets the requirements of GI "O'zenergonazorat" Order No. 168 of 09.09.2008.

3.4. Structure of energy consumption

Based on the rated power and average operating duration of each equipment group, the structure of electrical energy consumption at the "Dustlik" pumping station was reconstructed (Figure 1, panel a). The dominant share - approximately 84 % - is consumed by the main pumping units (centrifugal pumps with synchronous motors operating in the 1500–2000 kW range). The excitation and transformation system accounts for about 5 %, the drainage pumps for about 3 %, the bridge crane for about 2 %, control and metering equipment for about 3 %, and lighting and auxiliary systems for about 3 %.

Panel (b) of Figure 1 compares the actual operating performance of the 32D-19 pumping unit with its design (nominal) values. The largest performance gap is observed for the flow rate, which has decreased to approximately 82 % of the nominal value, indicating significant hydraulic wear and erosion of the impellers after more than 40 years of continuous service. The head and motor power have decreased to 95 %, while the efficiency has dropped from the design value of 85 % to approximately 78 %, representing a 7-percentage-point degradation. This level of performance decline corresponds to the typical aging behavior of centrifugal pumping units in irrigation service and confirms the need for systematic modernization measures.

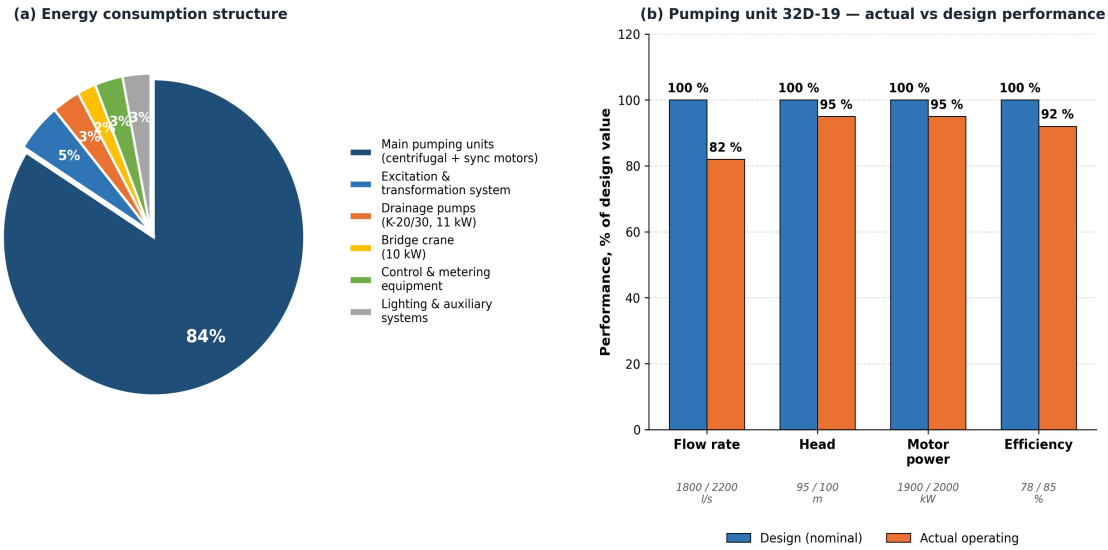

Figure 1. Energy and performance characteristics of the "Dustlik" pumping station: (a) structure of electrical energy consumption among the principal equipment groups; (b)

comparison of actual operating performance of the 32D-19 pumping unit against its design (nominal) values.

4. Discussion

The results obtained in this study clearly demonstrate that the energy performance of the "Dustlik" pumping station, like that of many similar facilities of the Soviet era, has degraded measurably during more than four decades of continuous service. The 18 % reduction in flow rate observed for the 32D-19 pumping units is consistent with the data reported for analogous facilities in the region, where progressive impeller erosion, increased internal clearances, and seal wear typically reduce volumetric efficiency by 15–25 % over a 30–40-year operational period [6]. The 7-percentage-point drop in efficiency translates directly into elevated specific energy consumption per cubic meter of water lifted, with corresponding implications for the operating costs of agricultural water supply.

The energy consumption structure identified in Figure 1a confirms that any meaningful energy-saving intervention must be directed primarily at the main pumping units, which alone account for 84 % of the station's electricity intake. Replacing existing synchronous motors with high-efficiency motors of class IE4 (super-premium efficiency) or IE5 can yield a 3–6 % reduction in motor losses [7], while complete overhaul or replacement of impellers can restore flow rate and efficiency to within 5 % of the original design values [8]. Variable-frequency drives (VFDs), which adapt motor speed to the actual hydraulic demand, can yield additional savings of 10–20 % in scenarios where the irrigation load fluctuates significantly between vegetation and off-season periods.

From an operational standpoint, the introduction of an Automated System for Commercial Metering of Electrical Energy (ASKUE) is identified as a priority. Currently, the absence of automated metering and the use of a single-tariff regime limit the possibility of load-shifting and economic dispatch optimization. ASKUE deployment would enable transition to differentiated tariffs and provide real-time visibility of the load curve, which is a prerequisite for the implementation of demand-side energy management strategies. International experience indicates that the introduction of ASKUE alone - without changes to the underlying mechanical equipment - typically reduces operational electricity costs by 4–8 % through optimized load distribution [9].

Additional opportunities for improvement are identified in the auxiliary systems. The non-operational state of the ventilation system represents a clear safety and reliability concern, as it increases the thermal stress on the high-voltage motors during summer peaks. Restoration of forced ventilation, combined with the introduction of temperature monitoring sensors in the motor windings, would extend equipment service life and reduce the risk of unplanned outages. Restoration of ventilation is among the lowest-cost interventions available and would simultaneously contribute to better motor efficiency, since winding resistance increases with temperature.

Finally, the structural condition of the building, pressure pipelines, and pressure basins also influences the overall energy performance of the system. Leakage losses in the pressure network, even at moderate levels (3–5 % of the conveyed flow), translate into a proportional increase in the specific energy demand of the station. Comprehensive hydraulic audit of the pressure network, including pressure-based leakage assessment and pipe-condition monitoring, is therefore a necessary complement to the equipment-focused measures discussed above.

Several limitations of this study should be acknowledged. First, the analysis is based on the available technical documentation and operational reports of a single facility; broader

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generalization to other pumping stations of the Andijan UNSE system would require comparative case studies. Second, the estimates of the energy consumption structure presented in Figure 1a are based on load-balance reconstruction rather than on direct sub-metering, which means that the share allocated to individual auxiliary systems carries an estimation uncertainty of approximately ±1–2 percentage points. Third, the economic feasibility of the proposed modernization measures depends on the prevailing electricity tariffs, capital cost of imported equipment, and the availability of state support programs, which were not quantitatively modeled in this work. These aspects represent priority directions for future research.

5. Conclusion

As a result of the analysis of the main equipment and the energy consumption structure of the "Dustlik" pumping station, the dominant role of the pumping units and the high-voltage synchronous electric motors in the total electricity consumption of the station was established (approximately 84 % of the total intake). The efficient operation of the pumping station is directly determined by the technical condition of the equipment, the operating regime, and the rational use of electrical energy. The technical indicators of the pumping units, the power of the electric motors, and the energy consumption of the auxiliary equipment were studied in detail, and the principal sources of electrical energy losses were identified as long-term equipment operation, the decrease in the coefficient of performance over time, and the uneven distribution of loads across the operating cycle.

To increase energy efficiency, it has been shown that it is essential to introduce modern energy-saving technologies, including the use of high-efficiency (IE4–IE5) electric motors, optimization of the operating regimes of the pumping units through variable-frequency drives, and the introduction of automated control systems including ASKUE-based commercial metering. The restoration of the ventilation system, periodic overhaul of the impellers of the 32D-19 units, and the implementation of a leakage-control programme for the pressure network are identified as priority intervention measures. The systematic implementation of these recommendations is expected to reduce the specific energy consumption of the station by 12–18 % and to extend the equipment service life by 7–10 years.

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