ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 11, Issue 11, November 2024

Analysis and optimization of the energy balance of an irrigation pumping station

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ABSTRACT: The article presents an analysis of annual, monthly and daily water supply graphs of irrigation pumping stations. To provide these graphs, the active, reactive and full capacities of the pumping units, obtained from the network, were calculated by starting the pumping units with a step. On the example of the irrigation pumping station and the irrigation substation in the Tashkent region, the transformer of the type TM-2500/35/6 in a 6 kV voltage network is characterized by the full power, active power, reactive power, active power wastes and reactive power wastes consumed when one, two and three-run simultaneously.

I.INTRODUCTION

Currently, there are 1,693 pumping stations and 5,301 pumping units under the jurisdiction of the Ministry of water management of the Republic. Of the existing pumping stations, 40 are large pumping stations. Total irrigated areas in our country are more than 4300 thousand hectares, of which 2276.3 thousand hectares are irrigated using 4069 units of pumping units. Republican irrigation pumping stations pump units are mainly equipped with short-circuit rotor asynchronous engines with a low-voltage capacity of up to 200 kW and a high-voltage capacity of 250 kW to 1250 kW. Low – voltage electric drives with asynchronous motors are 33.56%, high-voltage asynchronous drive-32.65%. To provide pumping stations with reliable electricity, they have their own substations. Of great practical importance are the energetic indicators of the electric grid when starting pumping units with a step based on the requirements for irrigation water. The energetic indicators of the electrical network depend on the ratio of the power of the interaction of the values of full power S, Active Power P and reactive power Q, the coefficient of power $\cos\varphi$ and the useful coefficient of work of the asynchronous motor η. In the study of energy consumption of the pumping station, it is important to take into account the indicators of high voltage transmission lines, high voltage changing Transformers [1-4].

II. SIGNIFICANCE OF THE SYSTEM

The analyzed irrigation pumping station system plays a critical role in water management for agriculture, particularly in regions where water resources are scarce or seasonal. By accurately measuring and optimizing the active, reactive, and full power capacities, the system supports efficient energy use, reducing operational costs and minimizing power waste. This efficiency is essential because irrigation is one of the largest consumers of electricity in agricultural settings. Furthermore, the system helps prevent energy losses and enhances the reliability of water supply, which is vital for maintaining consistent crop yields and supporting local economies.

III. LITERATURE SURVEY

The operating modes of irrigation pumping stations are determined by the water consumption graph, that is, these operating modes are formed in combination with arable land. In accordance with these modes, water supply is carried out. The water consumption mode is usually characterized by daily, monthly and annual water consumption graphs. Figure 1 shows the annual graph of water supply at the irrigation pumping station in Tashkent region [5,6,13,15].

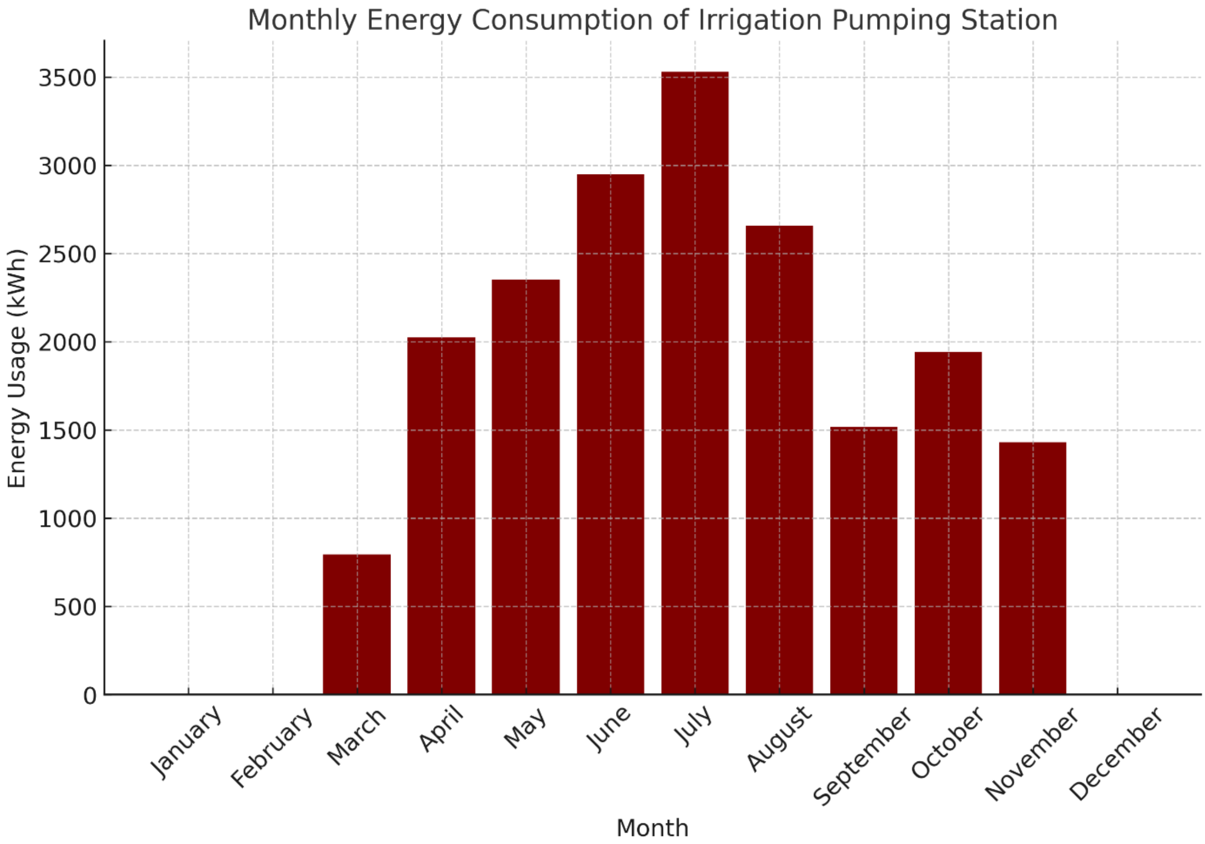

Fig 1. Annual chart of water supply of irrigation pumping station

The annual Tidal graph varies depending on what is planted in irrigation areas and on the irrigation technologies without being an invariable quantity. The values of water consumption in the annual water supply chart vary depending on the climatic conditions of the lunar days. For example, if in April 2025 thousand m3 of water was delivered, then during the month there is no water rise from 68 thousand m3 every day, but if at the beginning of the month 500 thousand m3 of water is delivered, then by the end of the month 1525 thousand m3 of water will be delivered in connection with the warming of The number of working pumping units is important in this process, and when adding one unit, the water consumption is low, and if two units meet, the water consumption is increased by the demand. Taking into account this, it is recommended to apply the pumping station adjustable electric drive pumping units.

IV. METHODOLOGY

The main task of the irrigation pumping station is to irrigate agricultural crops and gardens with a total area of about 2370 hectares. The installed capacity of the station is $R\Sigma = 3780$ kW, the productivity is $Q\Sigma = 8.2$ M^3/s, the lifting height is NS = 21 m. At the same time, the depth of the channel is $N_{depth} = 2$ m. The water lifting technology is as follows: irrigation water flows through the Chirchiq – Ahongaron irrigation system and Damariq canal barrier structure with its own flow into an irrigation pumping station with a width of 4.5 m, a depth of up to 2 m and a length of 635 m, then through the garbage barrier device enters the vanguard of the direct station. After this, irrigation water destined for irrigation purposes is obtained by centrifugal pumps of the irrigation water lifting pumping station and supplied to the water discharge facility by pressure pipes, and then distributed through derivation channels.
In the machine Hall of the irrigation pumping station (fig. The diameter of the total pressure pipe is 1.4 m, the length is 670 m. Separate pressure pipes consist of a diameter of 0.8 m and a length of 670 m.the water that a pumping unit is carrying passes through the reverse valve, elbow and sliding valves. When passing through the reverse valve, additional loading for the electric drive motor occurs.

Fig 2. View of the machine Hall of the irrigation pumping station

In the machine Hall of the irrigation pumping station, horizontal pumping units of 5000D-32 (24ndn) with an asynchronous motor power unit with a yield pressure of H = 32 m and A4-450 U-8UZ type capacity of R = 630 kW are installed, with six identical types of centrifugal, productivity (water consumption) Q = 5000 m^3 / h. The starting of the pumping units asynchronous engine is carried out by direct connection from the TM-2500/35/6 transformer to the supply network through the local control cabinet in the following sequence.
Power supply of the irrigation pumping station, TM-10000/110/35 type power comes to the irrigation substation through a 35 kv high-voltage power transmission line fidir "pump" at a distance of 5.5 km from the transformer substation "Turkestan". In the irrigation substation, a 6 kv voltage is transmitted to the machine hall through two TM - 2500/35/6 type transformers (Figure 3).

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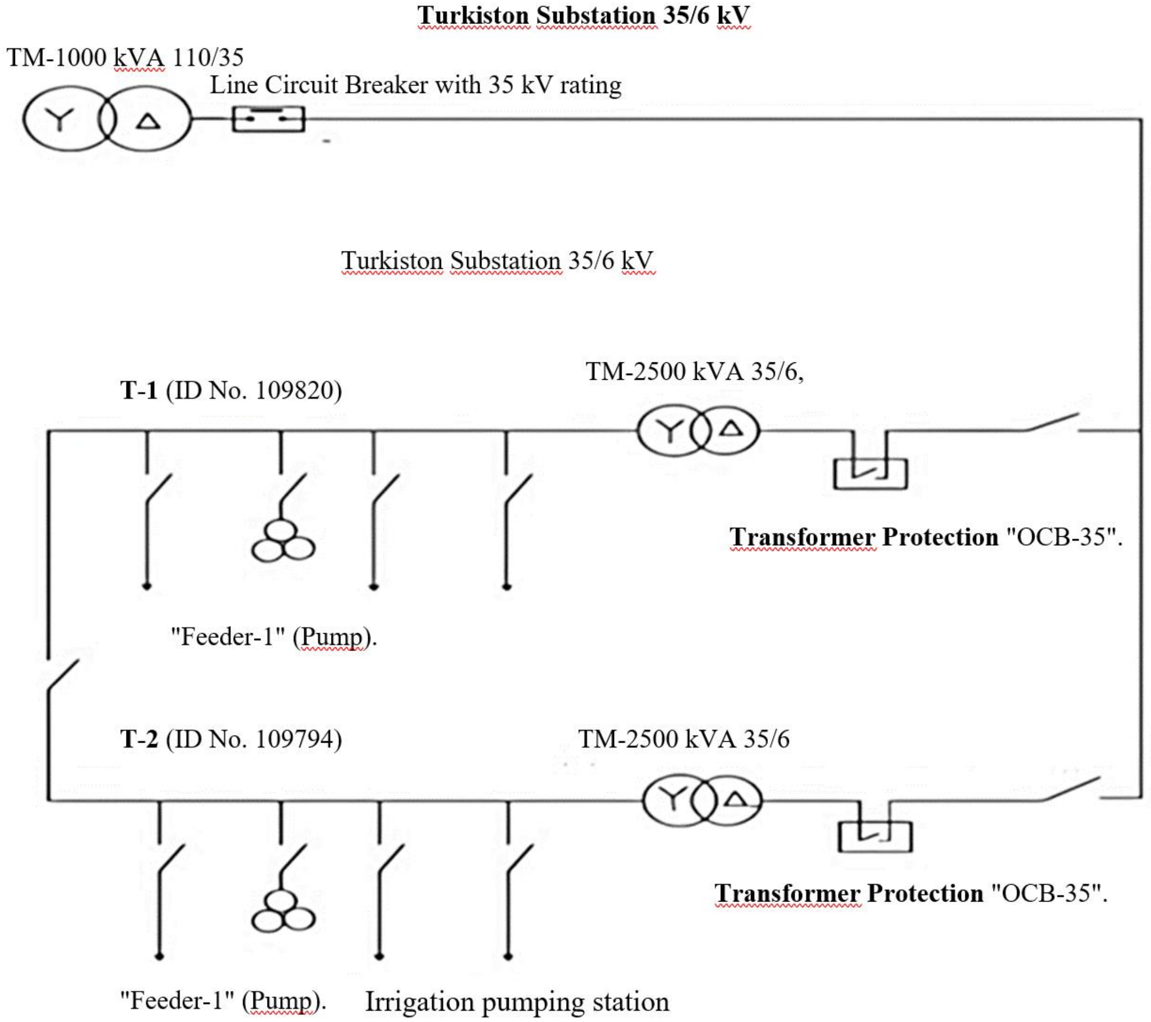

Figure 3. Irrigation pumping station is a one-line electrical scheme of power supply.

Power supply of the irrigation pumping station, TM-10000/110/35 type power comes to the irrigation substation through a 35 kv high-voltage power transmission line fidir "pump" at a distance of 5.5 km from the transformer substation "Turkestan". In the irrigation substation, a 6 kv voltage is transmitted to the machine hall through two TM - 2500/35/6 type transformers (Figure 3).

V. EXPERIMENTAL RESULTS

To drive the D5000 – 32 pump unit, short – circuit rotor asynchronous motors with A4-630-4U3 power output of 630 kW, voltage Un =6000 V, rotation speed nn=740 rpm, useful work factor η = 94.5%, power factor cosϕ=83%, stator current Ic=77.5 A are used. On the shaft of the pumping unit, the generated active power at its nominal values is calculated as [7,8,9]:

$$P_{\text{pump}} = \frac{\gamma * Q_n * H_n}{102 * \eta_{\text{pum}}} = \frac{1000*1,4*32}{102*0,8} = 549 \text{ kW} \quad (1)$$

in this case, $H_н$, $Q_н$ - the nominal pressure of the pump unit and the water consumption, γ – liquid density, $\eta_{нас}$ – The efficiency of the pump.

The pump power decreases as a result of suction of the working part and an increase in the gap between the working part and the drain.

The active power consumed by the pump-actuating asynchronous motor from the mains will be equal to:

$$P_{\mathrm{AM}} = \frac{P_{\mathrm{pump}}}{\eta_{\mathrm{AM}}} = \frac{549}{0,945} = 581\ \mathrm{kW} \quad (2)$$

The reactive power that consumes the asynchronous motor driving the pump from the power grid will be equal to

$$Q_{AM} = P_{AM} * tg\varphi = 581 * 0,67 = 389\ \mathrm{kVAr} \quad (3)$$

In this case $tg\varphi = \frac{\sqrt{1-cos\,\varphi_n^2}}{cos\varphi} = \frac{\sqrt{1-0,83^2}}{0,83}$=0,67;

The full power that the asynchronous motor that drives the pump is consuming from the power grid will be equal to

$$S = \sqrt{P_{AM}^2 + Q_{AM}^2} = \sqrt{581^2 + 389^2} = 699\ \mathrm{kVA} \quad (4)$$

We determine the reactive power of the TM-2500/35/6 transformer in idling mode and at the time of operation of one pump unit. Transformer passport data idling current I_0 = 1%, short circuit voltage U_k = 6.5%, full transformer power 2500 kVA.

We calculate the reactive power in the idling mode of the transformer [10-14].

$$Q_0 = \frac{I_{\%} * S_n}{100} = \frac{1*2500}{100} = 25\ \mathrm{kVAr} \quad (5)$$

We calculate the reactive power in the mode of operation of the transformer with nominal power.

$$Q_{p.n.} = \frac{U_{k\%} * S_n}{100} = \frac{6.5*2500}{100} = 162.5\ \mathrm{kVAr} \quad (6)$$

We calculate the total reactive power in the mode of operation of the transformer with nominal power.

$$Q_n = Q_0 + Q_{p.n.} = 25 + 162.5 = 187.5\ \mathrm{kVAr} \quad (7)$$

We calculate the reactive power in the mode of operation of the transformer with one pumping unit. In this case, the load factor of the transformer will be equal to the following.

$$\beta = \frac{S_{1PU}}{S_n} = \frac{700}{2500} = 0.28 \quad (8)$$

$$Q = \frac{S_{nom}}{100} * (I_0\% + U_k\% * \beta^2) = \frac{2500}{100} * (1 + 6,5 * 0,28^2) = 38\ \mathrm{kVAr} \quad (9)$$

VI. CONCLUSION AND FUTURE WORK

From the values determined above, when one, two and three pumping units worked at the pumping station, we calculate the active and reactive capacities that we consume from the last Network:
On active power, one pump unit consumes 581 KW*h when running, 1,162 KW*h when two pump units run concurrently, and 1,743 KW*h when three pump units run concurrently.
When one pump unit operates on reactive power, 389 kVAr*hours of energy are consumed in the asynchronous engine and 38 kVAr*hours in the transformer. When two pumping units run simultaneously, 778 kVAr*hours of energy is consumed in asynchronous engines and 76 kVAr*hours in a transformer. When the three pumping units run simultaneously, asynchronous engines consume 1,167 kVAr*hours of energy and transformer 140 kVAr*hours.

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