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METHODOLOGY FOR DETERMİNİNG THE DEMAND FOR ELECTRİCİTY AT PUMPİNG STATİONS USED İN AMELİORATİON AND WATER MANAGEMENT

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Abstract

The article discusses the methodology for determining the demand for electricity at pumping stations operated in the fields of land amelioration and water management. The article also presents the issues of using mutually complementary calculation and normative methods of electricity demand.

Keywords: pumping stations, electricity consumption, transformer, manometer, vacuummeter, pressure pipe, coefficient of hydraulic friction.

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1. **Introduction:** Subartesian wells and pumping stations are widely used in the system of amelioration and water management of the Republic in accordance with the existing water requirements depending on the natural conditions of various sections.

Pumping stations in the system of amelioration and water management of the Republic operate in stationary and mobile nature, providing electricity and fuel according to their sources of nutrition. They are designed to transport water from water bodies to distances located at certain distances, or to transport water from highways and irrigation canals to a certain height.

Pumping stations installed on natural and artificially created reservoirs on the Kura and Araz rivers, which are the main water arteries of the republic, provide water supply to irrigation and water supply systems.

In addition, stationary pumping stations are used to transport collector-drainage waters discharged from amelioration areas in the Republic.

The irrigation systems departments of the “Regional Water Amelioration Service” public legal entity of the Azerbaijan State Water Resources Agency operate 605 pumping stations with a total capacity of more than 944000 kW, and more than 137 subartesian wells with a total capacity of 7000 kW [1, 2].

845 units are operated for irrigation purposes from these pumping stations. 593 of them are electric, 160 are fuel and 135 are mobile pumping stations. 56 pumping stations are being operated for amelioration purposes. 38 of them are electric and 18 are mobile pumping stations.

The number of floating pumping stations is 163. Of these, 86 work on electricity, 77 on fuel.

2. Object and methodology of research. The existing pumping stations under the management of irrigation systems of the "Regional Water and Amelioration Service" public legal entity were taken as the object of the study. The studies carried out were carried out in accordance with the methodology based on the method of comparative analysis of the demand for electricity at pumping stations.

3. Research results, analysis, and discussion. The results of the studies carried out in the direction of improving the rules for setting fuel and electricity consumption norms at pumping stations used in the fields of irrigation systems departments of the "Regional Water and Amelioration Service" public legal entity were analyzed.

As a result of the research work carried out, the calculation sequence of electricity demand at pumping stations used to create the required pressure in closed irrigation networks by taking water from natural sources in water supply, amelioratin, irrigation and agriculture, pumping water into main channels, as well as pumping water into the sea in collector-drainage networks was given [6].

Here, two methods are used that mutually complement each other in the demand for electricity.

The first method - it is called the calculation method, and the demand for electricity is determined by means of technical reports.

The second method – it is called the normative method. The determination of the consumption of electricity in this method is based on special norms.

The calculation method is more accurate than the normative method, but it is difficult to perform, since it is required to determine the required indicators.

In the normative method, passport indicators of pumping units are mainly used [3, 6].

Method of calculating the demand for electricity at pumping stations

To carry out the calculation method, it is necessary to collect data on the change in the performance indicators of the pumps in the system, the water level and pressure, and many other parameters like this.

The annual consumption of electricity is calculated as the sum of the electricity consumption in all units, as well as the sum of the electricity losses in the power grid and power transformers, subject to technical justification.

Annual electric energy consumption (KW·h/year) is defined as the total consumption of the system by summing the consumption of electricity in each mode of each pump unit by the following expression:

$$W = 2{,}72 \cdot 10^3 \cdot \sum_{i=1}^{n} (\frac{Q_1\, H_i}{\eta_1} t_i) \qquad (1)$$

here: W - annual electricity consumption, kWh/year;

i - index indicating the mode of operation of the aggregates;

n - number of operating modes of aggregates;

Q_i – productivity of the pump in i-mode, m^3/h;

H_i - full pressure of the pump in i-mode, m;

η_i - coefficient of useful work of the aggregate in i - mode;

t_i - is the working time of the unit in i - mode, h/year.

The full pressure in pumps is defined as the difference in pressures in pressurized and suction pipes by the following expression:

$$H = H_m \pm H_v + H_o + \frac{V_m^2 - V_v^2}{2 \cdot 9{,}81}, \qquad (2)$$

here: H_m - manometer index, m;

H_v- indication of the vacuummeter (“- ”corresponding to the excess pressure, " + " corresponding to the discharge pressure);

H_o - the distance between the places of installation of the manometer and the vacuummeter in the vertical direction, m;

V_m, V_v - it is the speed of water at the junction of the pressure gauge and vacuummeter (determined based on the consumption of water passing through the live cross-section of the suction and pumping pipes), m/sec.

$$\frac{V_m^2 - V_v^2}{2 \, x \, 9{,}81} = 0{,}0872 \cdot Q^2 (\frac{1}{d_2^4} - \frac{1}{d_1^4}), \qquad (3)$$

here: Q - pump consumption, m^3/s;

d_1, d_2 - the inner diameter of the suction and injector pipes at the manometer sites, m.

Pressure losses in a pressurized pipe are designated by the following expression [3].

$$\Delta H = \lambda \frac{L V^2}{D \, 2 \, g}, \qquad (4)$$

here: λ - hydraulic friction coefficient;

L - length of pressure pipe, m;

D - internal diameter of the pipe, m;

V - fluid flow rate, m/s;

g - free fall momentum, g = 9.81 m^2/s.

The coefficient of hydraulic friction depends on the Reynolds number and is determined by the roughness coefficient of the pipe:

$$R_e = \frac{DV}{\nu}, \qquad (5)$$

here: ν - kinematic viscosity coefficient, m^2/s.

In many cases, the required electrical energy is determined based on the specific consumption of the pumped water as follows [3, 4]:

$$\dot{I} = \frac{P}{Q}, \frac{kVt}{m^3/hour} \qquad (6)$$

here: İ - required electric energy;

P – power of aggregate, kW;

Q - products of pump, m^3/h.

The energy saving during the operation of the pumps can be determined by the following wording, adding the hydraulic loss coefficient to the method proposed by B.S. Lethnov [4]:

$$W_{ek} = \frac{(N_b\ T)\cdot(W^x_{эк})}{\eta_{eng.}} \cdot \varphi \cdot \Delta H, \qquad (7)$$

here: W_{ek}- saving electricity during pump operation, kWt;

T - working time, h;

N_b - useful working coefficient of engines;

η_{eng}- useful operating factor of engines;

$W^x_{эк}$- it is determined according to the graph, being the relative savings in electricity;

ϕ - coefficient taking into account the number of working pumps;

Δ H - hydraulic losses during parallel operation of pumps.

The coefficient of useful work (movement) of pumping stations is determined according to their passport indicators. If the actual prices of the units obtained from the measurement are known, then using them one can calculate the coefficient of useful operation of pumping stations. The coefficient of coefficient of pumping stations is determined depending on the coefficient of coefficient of pumps, electric motors and connecting devices (coupling) as follows:

$$\eta = \eta_N \cdot \eta_{e.m.} \cdot \eta_{Coupling}\ , \qquad (8)$$

here: η_N- useful operating coefficient of the pump;

e.m.- useful coefficient of electric motor operation;

$\eta_{Coupling}$- coupling coupling coefficient 1 is accepted.

When new pumping stations are put into operation, it is recommended to use the maximum, average and minimum productivity of the pumps in three modes of operation, as the productivity (Q) and full pressure (H) of the pumps.

The power consumption of existing pumping stations is determined according to the operating log according to several operating modes of pumps and their operating time. According to the first lifting height of the collector-drainage waters of pumping stations, 2-3 modes are allocated during the year. Several operating modes are selected for each unit, depending on the terrain relief according to the height of the second, third and subsequent lifting. For these modes, the amount (consumption) of water pumped by the pump for 24 days, that is, the hourly productivity and pressure indicators of the pump, are recorded in the operating log. For the first lifting height, indicators are recorded for 12 days.

The electricity consumption of other devices, including the raising of valves, lifting and conveying mechanisms, drainage pumps, electric heaters, lighting, and ventilation systems, is determined by the following expression:

$$W = N \cdot K \cdot T, \qquad (9)$$

here: W - is the amount of electricity consumed, kW;

N - is the rated power of aggregates that require electricity, kW;

K - is the load coefficient of the aggregate. The operating time, being a certain part of the rated power of the unit, is determined experimentally;

T - during the year is the working time of the aggregate, h.

Electrical power losses in power transformers are designated by the following expression::

$$W_T = (P_{b.q.} + P_{q.q.} \cdot K^2)\mathrm{T}, \qquad (10)$$

here: W_T - electrical power losses in the power transformer, kWh;

P $b.q$, $P_{q.q.}$- it is the losses of electrical energy generated by Transformers in idle walking and short circuit. It is assigned according to the passport indicators of the transformer;

K - transformer load coefficient;

T- during the year is the working time of the transformer, and T=8760 hours is accepted.

Losses up to the area operating aggregates in the power grid are assumed to 1% of the total losses. Power losses in power transformers are assumed to be 2.6% of the rated power of the transformer.

Determination of electricity demand by normative method

Electricity consumption in pumping (lifting) water is determined by the use of each pump and other auxiliary devices at pumping stations (electric valve, lifting and conveying mechanisms, drainage pumps, lighting system and etc.). Calculated according to the consumption of electricity [6].

The energy consumption for pumping (lifting) water at individual pumping stations is determined by the following expression:

$$W = W_N \cdot W_y + W_{k\,q} + W_{vent.}, \qquad (11)$$

here: W_N - this is the specific consumption of electricity required for pumping (lifting) water by a pump system, kWh/1000 m^3. It is assigned according to table 1.

W_y-is the volume of water pumped (lifting) by pumping stations during the year, 1000 m^3;

$W_{k\,q}$ - auxiliary devices (electric drawers, lifting and conveying mechanisms, drainage pumps, lighting and etc.) is the annual consumption of electricity consumed, 1000 kWh. These indicators are assigned according to table 2;

$W_{vent.}$- the annual electricity consumption required for ventilation at pumping stations that raise water to a height is, 1000 kWh. These indicators are assigned according to table 2.

Table 1. Specific consumption of electricity for pumping water to a height

Full pressure, m	**Specific consumption of electricity, kVt.saat/1000 m³**	
	Pumping stations operated in water supply	**Pump stations that hit the water into the canals**
10	39	44
20	76	83
30	113	124
40	150	167
50	187	211
60	224	257
70	260	304
80	297	353
90	334	404

Table 2. Consumption of electricity spent on auxiliary (auxiliary) devices-mechanisms at pumping stations

Indicator names	**Productivity of pumping stations , 1000 m³/day**					
	< 5	**6-25**	**26-50**	**51-100**	**101-200**	**>200**
Annual consumption of electricity, 1000 kWh/year	5	47	90	185	310	400

Additional consumption of electricity for ventilation, 1000 kWh/year	2	6	10	15	20	25

A simple method of calculating the electricity used for pumping and supplying (discharged) the water needed for farms in amelioration and irrigation systems

The norm of electricity consumption spent on lifting and supplying water to farms in production conditions is calculated according to the following simplified expression for lifting 1000 m^3 of water [5]:

$$W_t^o = \frac{2{,}72H_{t.t}}{\eta}, \qquad (12)$$

here: W_t^o - The consumption rate of electricity required for pumping 1000 m^3 of water, $\frac{kWh}{1000m^3}$;

$H_{t.t}$ – total pressure for water rise, m;

$\eta = \eta_N \eta_{э.м} \eta_{Coupling}$ – useful working coefficient of pumping stations;

η_N – the coefficient of useful operation of the pump (determined according to the passport of the pump);

$\eta_{e.м.}$ – useful working coefficient of the electric engine (determined based on the passport of the engine);

$\eta_{Coupling}$ – the coefficient of useful operation of the connecting coupling is taken $\eta_{Coupling}$=1.

The calculation of the full pressure of the pumps is determined according to their passport indicators when the pumps are operating in optimal mode .

$$H_{t.t.} = H_m \pm H_v + H_0 + \frac{V_m^2 - V_v^2}{2g}, m. \qquad (13)$$

here: $H_{t.t.}$ – total pressure, m;

H_m – indicator of manometer, m;

H_v - indication of the vacuummeter (“- ”corresponding to the excess pressure, " + " corresponding to the discharge pressure);

H_0 – the distance between the joints of the manometer and the vacuummeter in the vertical direction, m;

V_m, V_v – the speed of water at the confluence of the manometer and the vacuummeter in the suction and pumping pressure pipes, m/san;

$g = 9{,}81\ m/s^2$ – free fall momentum,

If the diameter of the suction and injector pressure pipes is the same, then

$$\frac{V_m^2 - V_v^2}{2g} = 0.$$

In the amelioration and irrigation systems, the consumption rate of electricity required for the volume of water required by the consumer is determined according to the average consumption rate of all pumping units operating in the system by the following expression:

$$Q_t^{N.st.} = \frac{\sum_1^n Q_T^N q^n T^n}{\sum_1^n q^n T^n}, \frac{kWh}{1000\ m^3} \tag{14}$$

here: $Q_t^{N.st.}$ - the consumption rate of electricity required for lifting and pumping water required by the consumer, $\frac{kWh}{1000\ m^3}$;

Q_T^N, - electricity consumption rate for each pump, $\frac{kWh}{1000\ m^3}$;

q^n – nominal (according to passport) productivity of each pump, $m^3/hour$;

T – duration of each pump operation, hour.

The norm of consumption of the total required electricity is determined by the following expression:

$$Q_{gen.}^{N.st.} = Q_t^{N.st.} + \frac{W_{aux.d}^{N.st.}}{V}, \frac{kWh}{1000\ m^3} \tag{15}$$

here: $Q_{gen.}^{N.st.}$ – total electricity consumption required for pumping stations, $\frac{kWh}{1000\ m^3}$;

$W_{aux.d}^{N.st.}$, - consumption of electricity spent on auxiliary devices (lighting, ventilation and other losses) at pumping stations, 1000 kW ∗ h. These indicators are set from a special table.

V – is the volume of water lifted and discharged by pumps, $1000\ m^3$.

In general, the norm of electricity required for the volume of water lifted and discharged by pumping stations is determined as follows:

$$W^{N.st.} = Q_{gen.}^{N.st.} V$$

here: $W^{N.st.}$ - total required electricity consumption for pumping stations, $kW \cdot h$;

$Q_{gen..}^{N.st.}$ – total required electricity consumption rate for pumping stations, $\frac{kW \cdot h}{1000\ m^3}$;

V – is the volume of water pumped, $1000\ m^3$.

Example of calculation of electricity consumption required for lifting and discharging water required in amelioration and irrigation system

Pumps of the brands 2KM-6 and 3K-9 were used to lifted and discharge water to farms.

Preliminary indicators for conducting the report are given in table 3.

Table 3. Preliminary indicators for calculating the norm of electricity consumption for lifting and discharging the required water

Indicators	**Brand (type) of pumps**	
	2KM-6	**3K-9**
Productivity, m^3/h	20	30
Pressure, m	30,8	34,8
Power of electricity engine, kW	4,5	7,2
Coefficient of pumping	0,64	0,62
Coefficient of electricity engine	0,84	0,845
Coefficient of the connecting coupling	1	1
Pump operating time, hour	720	720

The consumption rate of electricity per 1000 m^3 volume of water raised and pumped (discharged) by each pump is determined as follows:

For 2KM-6 brand pump:

$$W_t^1 = \frac{2{,}72 H_{t.t.}}{\eta} = \frac{2{,}72 \cdot 30{,}8}{0{,}64 \cdot 0{,}84 \cdot 1} = 155{,}8\ \frac{kW \cdot h}{1000\ m^3}$$

For 3K-9 brand pump:

$$W_t^2 = \frac{2{,}72 H_{t.t.}}{\eta} = \frac{2{,}72 \cdot 34{,}8}{0{,}62 \cdot\ 0{,}845 \cdot 1} = 180{,}7\ \frac{kW \cdot h}{1000\ m^3}$$

The total consumption rate for both pumps is calculated as follows:

$$Q_t^{N.st.} = \frac{W_t^1 q^1 T^1 + W_t^2 q^2 T^2}{q^1 T^1 + q^2 T^2} = \frac{155{,}8 \cdot 20 \cdot 720 + 180{,}7 \cdot 30 \cdot 720}{20 \cdot 720 + 30 \cdot 720} = 170{,}7 \frac{kW \cdot h}{1000\ m^3}$$

Table 4. Pumping stations established by the “Design of water and amelioration complexes" İnstitute pumping stations were established in the project to provide the area with water

	water-supplie	**Hydro-module ordinate**	**water consu-**	**pumps brand**	**engine**	**quan-tity**	**power of 1**	**total power of**	**Geo-metric**

working project name	d area, ha	(netto), *l/sec*. ha	mption, m^3/s		brand		pump unit, kW	pump station, kW	pres-sure, m
Continuing cons- truction of Yukhari Mil Canal 3325ha (total) a) Water supply area of pumping station №1 b) Water supply area of pump station №2	16 00 17 25	0,579 0,579	1,20 1,30	AD- 2000- 100a-2 AD- 2000 100a-	A44 50x6 43 A44 5 0x64 3	4 4	630 630	19 40 19 40	7 2 72, 5
The construction of the Yukhari Mil Canal is ongoing. Indicators of existing pump station №3 of type IV release complex	5725	0,579	1,13 4	21D1 250- 63a	5AM H 315- M49 3	4	250	1100	42

Note: 1. In the project "Providing the farm with irrigation water" with an area of 3120 ha in the territory of Yevlakh and Goranboy regions, 2.0 electric pumping stations with a productivity of Q=2.0 m^3/sec were designed.

2. In the project "Measures to provide irrigation water to arable land in Jojug Marjanli village of Jabrayil district", a pumping station with H = 25 m and Q= 0.56 m^3/sec was designed to raise water from the Araz River.

Example. Calculation of the electricity demand of pumping stations number 1 and 2 for water supply of 3325 ha area and at the same time for pumping station number 3 for water supply of 5725 ha area by " Design of water and amelioration complexes " Institute.

The report is carried out in the following sequence.

Table 5. Technical indicators of pumps

Indicators	Brand of pumps		
	AD2000-100a-2	**AD2000-100a-2**	**1D1250-63a**
Productivity, m^3/h	1900	1900	1100
Pressure, m	72	72,5	42
Power of electricity engine, kW	630	630	250
Coefficient of pumping	0,64	0,64	0,64
Coefficient of electricity engine	0,84	0,84	0,84
Coefficient of the connecting coupling	1	1	1
Pump operating time, hour	720	720	720

The norm of electricity consumption per volume of raised water $1000\ m^3$ for each pump is calculated as follows:

AD2000-100a-2 for proprietary pump No. 1:

$$W_t^1 = \frac{2{,}72 \cdot H_{t.t}}{\eta} = \frac{2{,}72 \cdot 72}{0{,}64 \cdot 0{,}84 \cdot 1} = \frac{195{,}84}{0{,}54} = 362{,}67 \frac{kVt \cdot saat}{1000m^3}$$

AD2000-100a-2 for proprietary pump No. 2:

$$W_t^2 = \frac{2{,}72 \cdot H_{t.t}}{\eta} = \frac{2{,}72 \cdot 72{,}5}{0{,}64 \cdot 0{,}84 \cdot 1} = \frac{197{,}20}{0{,}54} = 365{,}19 \frac{kVt \cdot saat}{1000m^3}$$

1D1250-63a for proprietary pump No. 3:

$$W_t^3 = \frac{2{,}72 \cdot H_{t.t}}{\eta} = \frac{2{,}72 \cdot 42}{0{,}64 \cdot 0{,}84 \cdot 1} = \frac{114{,}24}{0{,}54} = 211{,}56 \frac{kVt \cdot saat}{1000m^3}$$

The total electricity consumption rate for every 3 pumps is calculated as follows:

$$Q_t^{N.st.} = \frac{W_t^1 \cdot q^1 \cdot T^1 + W_t^2 \cdot q^2 \cdot T^2 + W_t^3 \cdot q^3 \cdot T^3}{q^1T^1 + q^2T^2 + q^3T^3}$$
$$= \frac{362{,}67 \cdot 1900 \cdot 720 + 365{,}19 \cdot 1900 \cdot 720 + 211{,}56 \cdot 1100 \cdot 720}{1900 \cdot 720 + 1900 \cdot 720 + 1100 \cdot 720}$$
$$= \frac{689073 + 693861 + 8885{,}52}{1900 + 1900 + 1100} = \frac{1391819{,}52}{4900{,}0} = 284{,}04 \frac{kW \cdot h}{1000\ m^3}$$

4. Result

The methodology for determining the demand for electricity for pumping stations operating on electric energy used in the fields of amelioration and water management has been developed. At the same time, the annual energy consumption at pumping stations by calculating the consumption of electricity in each mode of each pumping unit, the total consumption of the system was determined and the energy losses contained in the system were determined.

5. References

[1] Ahmedzade A.S., Hashimov A.S. Cadastre of Amelioration and Water Management Systems. Baku, Azerneshr, 2006, p. 272.

[2] Hasanov S.T., Gulmammadov Ch.C. Reasons for the Emergence of Direct Energy Losses in Electric Pump Stations. AzHvəM EIB, Collection of Scientific Works, Volume XXXIII, Baku, 2013, pp. 246–250.

[3] Gruntovich N.V., Kapansky A.A. Calculation-Analytical Method for Standardizing Consumption in Water Supply and Sewerage Systems. Vestnik GGTU im. P.O. Sukhogo, No. 2, 2015.

[4] Leznov B.S. Methodology for Calculating Energy Savings Using REP in Pump Installations. Association of Thermal Engineering and Engineering Companies, Article Catalog, 2010.

[5] Methodological Recommendations for Standardizing Fuel and Energy Resources for Organizations of the Ministry of Agriculture and Food System of the Republic of Belarus. Minsk, 2017.

[6] Methodological Recommendations for Determining the Need for Electric Energy for Technological Purposes in the Field of Water Supply, Sewerage, and Wastewater Treatment. Moscow, 2007.