Technique of A Feasibility Study for the Use of a Variable Frequency Drive in Pumping Units

Khafizov Islom Ikramovich	Ph.D., docent Bukhara Engineering-Technological Institute
Hafizov Xudoyor Islomovich	Master Student Bukhara Engineering-Technological Institute
Ahmadov Elmurod Kamol o'g'li	Master Student Bukhara Engineering-Technological Institute

ABSTRACT

The article presents the methodology of a feasibility study for the use of variable frequency drives in pump units. The calculation methodology of the application of the variable frequency drive in pump units is presented and it is proved that its application makes it possible to use large pump units in low-flow mode and, therefore, to reduce their total number. The problem of determining the technical and economic parameters of D-series pumps is also considered and it is shown that the linear dimensions of pump units grow much slower than their capacity and flow rate. An expression for determining the relative linear dimensions of the units being compared is given.

Keywords: Units, pump units, D-series

I. Introduction

Given the obvious advantages, the frequency-controlled electric drive is becoming quite widespread in pumping installations. At present, conditions have developed that make it possible to use it everywhere. Semiconductor technology development made it possible to create reliable and relatively inexpensive frequency-controlled electric drives based on static converters. As a result, work on research, development, and creation of pumping units equipped with an automated frequency-controlled electric drive has expanded.

II.Material and Methods

The use of a frequency-controlled electric drive-in pumping units makes it possible to use large pumping units in the low-flow mode and, consequently, reduce their total number. Here it is appropriate to say that more powerful units have higher technical indicators, including higher efficiency.

It is shown in [2] that the linear dimensions of pumping units grow much slower than their power and supply. As is known, the volumes (dimensions) of machines (electric motors, pumps, etc.) are proportional to the nominal values of their torque:

$$V = kM \qquad (1)$$

where M – is torque;and k – is the coefficient of proportionality.

If we express the moment in terms of the operating parameters of the pumping unit and extract the cubic root from both parts of the equation (1), we get the dependence of the linear dimensions of the unit on its main parameters:

$$L = \sqrt[3]{kM} = \sqrt[3]{k} * \sqrt[3]{\frac{QH}{\eta n}}, \qquad (2)$$

where Q – t ed; – is the pump unit head;; n – is the pump unit rotation speed and ;; η – is the unit efficiency.

III.Results

We believe that the head values of the compared units are approximately the same for the specific installation under consideration. We take the parameters of the smallest of the compared aggregates as the basic ones. For these conditions, after some transformations, we obtain an expression for determining the relative linear dimensions of the compared aggregates

$$L^* = \sqrt[3]{\frac{Q_l / \eta_l n_l}{Q_b / \eta_b n_b}}, \qquad (3)$$

where Q_l, η_l, n_l – are the nominal parameters of the larger unit; Q_b, η_b, n_b –are the nominal parameters of the base unit;

From expression (3), it follows that the linear dimensions of the enlarged unit in comparison with the basic unit increase to a lesser extent than its feed increases. This pattern has been tested on common domestic pumping units of the D series. Based on the actual dimensions of the D-series units taken from the catalog [2], the relative linear dimensions of six standard sizes of pumps in this series are calculated using the equation

$$L^*_{actual} = \sqrt[3]{\frac{l_l b_l h_l}{l_b b_b h_b}}, \qquad (4)$$

where l_l, b_l, h_l — dimensions (length, width, height) of the larger unit; l_b, b_b, h_b — dimensions (length, width, height) of the base unit.

Since the linear dimensions of pumping units increase more slowly than their supply increases, increasing the unit capacity of the units allows you to reduce their total number and reduce the size of buildings, simplify the hydraulic scheme of the station, reduce the number of pipe fittings and the number of cells in the electrical switchgear, etc.

By equipping the pump units with a variable frequency drive, reducing the number of units at the pumping stations does not reduce the operating capacity to change their operating modes caused by changes in water consumption.

Thus, the use of a frequency-controlled electric drive under certain conditions not only does not increase the capital investment but also reduces it somewhat (by a certain amount of DK).

Calculations have shown that the use of a frequency-controlled electric drive in combination with the enlargement of the unit power, depending on the purpose of the station and other specific conditions, can reduce the specified costs by 20-50 % [2].

The feasibility study of the use of a frequency-controlled electric drive in pumping units is carried out in the following sequence.

1. Make up hydraulic and electric circuit diagrams to compare the pumping systems.
2. Determine the composition of the main equipment of the compared pumping units: pumping units, valves, valves, check valves, cells of switchgear, and control devices (frequency converters, etc.).
3. They assemble the main equipment of the compared pumping units.
4. Determine the capital costs for the basic and new options for electrical equipment Кel, pumping equipment Крum, hydro-mechanical equipment Кhm, and construction part Кcon. The price lists of companies and equipment manufacturers determine the cost of electrical and hydro-mechanical equipment. For a preliminary estimate of the cost of a frequency-controlled electric drive and additional capital costs associated with the use of a frequency-controlled electric drive, the graphs shown in fig. 1. and 2. can be used. The cost of the construction part can be determined by the aggregated specific indicators of the cost of construction of pumping stations, contained, for example, in [3], taking into account the current inflationary coefficients of the cost of construction.
5. Determine the depreciation deductions A from the cost:

electrical equipment

$$A_{el} = A_{rel.un} K_{el};$$

pumping equipment

$$A_{pum} = A_{rel.un} K_{pum};$$

hydro-mechanical equipment

$$A_{hm} = A_{rel.un}K_{hm};$$

the construction part of the pumping station $A_{con} = A_{rel.un}K_{con};$

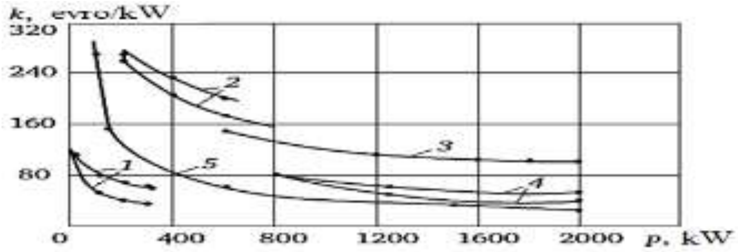

Fig.1. Specific cost of converters and control devices of various types of adjustable electric drive:

1 — low-voltage frequency converters; 2 — high-voltage frequency converters with dual voltage; 3 — high-voltage frequency converters; 4 — high-voltage transformer-free converters according to the valve motor system; 5 — hydraulic variator “Twin-Disk”.

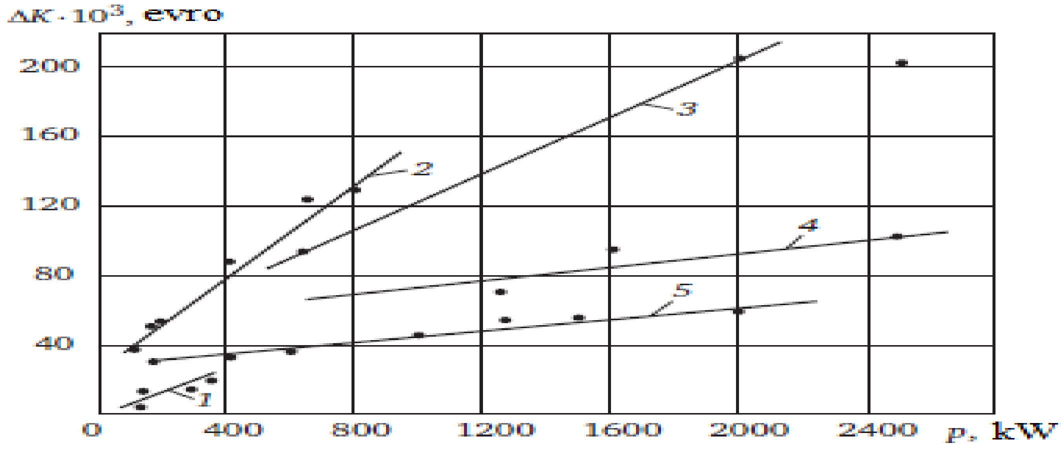

Fig.2. Additional costs associated with the use of converters and various types of controlled electric drive control devices: 1—5 — the same as in fig. 1

Approximate values of depreciation rates for various types of equipment are given in table 1.

Table 1

Depreciation rates by type of main equipment

Serial	Equipment types	Depreciation rate	
		A, %	$A_{rel.un}$
1	Pump equipment	19	0,19
2	Gate valves, gates, lves	21,3	0,213
3	Electrical equipment	8,3	0,083
4	Construction part	2,6	0,026

6. Determine the energy consumption W_{reg} in use frequency-controlled drive (FCD) in the automatic control system of the pumping unit, kWh,

$$W_{reg} = 0.25\frac{N_b T_{cal}\left(1+\lambda\right)}{\eta}\left[\left(1+H^*_{b.p}\right)+\lambda^2\left(1-H^*_{b.p}\right)\right]$$

7. Determine the energy savings, obtained as a result of a decrease in overpressure when using the FCD in the ACS of the pumping unit.

8. Determine the energy savings ΔW_η obtained as a result of the use of large capacity pumping units with higher efficiency η_{big}, in comparison with the units of the basic version η_b, kWh,

$$\Delta W_\eta = W_{reg}\left(1-\frac{\eta_b}{\eta_{big}}\right)$$

where $\eta_{big} > \eta_b$

9. Determine the energy consumption $W_{n.reg}$, kWh, of the pumping unit when the units are operating according to the basic version, without a frequency-controlled electric drive:

$W_{n.reg} = W_{reg} + W_{rec} + W.$

10. Determine the amount of water lost due to non-productive costs when operating in the basic mode. This volume of water corresponds to the volume of water saved when using a variable frequency drive in the ACS of the pumping unit $V_{sav.year}$.

11. Determine the decrease in the volume of non-productive water consumption, dumped into the sewer, when operating in the basic mode.

$V_{dec.dum.year} = \left(0{,}80 \div 0{,}85\right)V_{sav.year}$

12. Determine the electricity costs for the base case.

$$C_{el.b} = W_{n.reg}P_{el}$$

Where electricity tariff.

13. Determine the electricity costs for the new option (with the use of aggregates of enlarged capacity and FCD in the automatic control system of the pumping unit)

$C_{el.n} = W_{reg}P_{el}$

14. Determine the costs of covering the non-productive flow of clean water during the operation of the pumping unit without FCD.

$\Delta C_Q = P_Q P_{sav.year},$

where P_Q — the cost of 1m3 of clean water.

15. Determine the costs of processing and transporting wastewater in the wastewater system (sewers).

$\Delta C_q = P_q P_{dec.dum.year},$

where P_q — the cost of pumping and processing of wastewater.

16. Determine the number of capital costs for the basic $K\Sigma b$ and new $K\Sigma n$ options for electrical, hydraulic, and construction parts

$$K_{\Sigma b} = K_{el.b} + K_{pum.b} + K_{hm.b} + K_{con.b}$$

$$K_{\Sigma n} = K_{el.n} + K_{pum.n} + K_{hm.n} + K_{con.n}$$

17. Determine the amount of depreciation for the base $A_{\Sigma b}$ and new $A_{\Sigma n}$ options

$$A_{\Sigma b} = A_{el.b} + A_{pum.b} + A_{hm.b} + A_{con.b}$$

$$A_{\Sigma n} = A_{el.n} + A_{pum.n} + A_{hm.n} + A_{con.n}$$

18. Determine the number of operating costs for both options $C_{\Sigma b}$ and $C_{\Sigma n}$, taking into account energy consumption, saving clean water, reducing the discharge of effluents into the sewage system, and depreciation deductions

$$C_{\Sigma b} = C_{el.b} + \Delta C_Q + C_q - A_{\Sigma b};$$

$$C_{\Sigma n} = C_{el.n} - A_{\Sigma n}$$

19. Determine the reduced costs for both options

$$З_b = C_{\Sigma b} + EK_b;$$

$$З_n = C_{\Sigma n} + EK_n;$$

where E—is the coefficient of efficiency of capital investments, depending on the adopted payback period for additional capital investments:

$E = 1 / T_{pb}$

Payback period Tpb, year.	2	3	4	5	6
Coefficient E.	0,5	0,33	0,25	0,2	0,16

20. The reduction of the reduced costs,%, is calculated according to the new variant $З_n$ in comparison with the basic variant $З_b$,%

$$\Delta З = \frac{З_b - З_n}{З_b} 100.$$

The payback period of ACS equipped with a variable speed drive, taking into account the net water savings, reduction of wastewater discharge into the sewerage, and increase in the unit capacity of pump units is determined by the following expression

$$T_{pb} = \frac{\Delta K - dK}{\Delta C_{el} + \Delta C_{n.w} + \Delta C_{w.w} - A_{el}\Delta K + A_c dK},$$

where $\Delta K = K_{fcd} + K_{acs}$ —additional capital costs associated with the creation of an energy-saving ACS based on FCD; $dK = K_{\Sigma b} + K_{\Sigma n}$ —reduction of capital costs due to the enlargement of the unit capacity of pumping units and a decrease in their number;

$\Delta C_{el} = C_{el.b} - C_{el.n}$ — reduction in operating costs due to the use of a variable frequency drive in the ACS of a pumping unit and an increase in the efficiency of pumping units due to the enlargement of their unit capacity;

$\Delta C_{n.w} = \Delta C_Q$ — reduction in operating costs due to a decrease in excess pressure in the network and a reduction in non-productive water consumption due to the use of a variable frequency drive in the ACS of a pumping unit;

$\Delta C_{w.w} = \Delta C_q$ — reduction in operating costs due to a decrease in excess pressure in the network and a reduction in wastewater discharge into the sewage system due to the use of a frequency-controlled electric drive in the ACS of the pumping unit;

$A_{el} = 0,083$ — depreciation rate for electrical equipment;

$A_c = 0,026$ — depreciation rate for the construction part.

IV.Discussion

For the D-series pump units, the regularity is established that the linear dimensions of the enlarged unit increase less than the linear dimensions of the base unit. The results of calculating the relative parameters of the pumps of the D series, a pump unit equipped with a D320-70 pump are presented.

Due to equipping the pump units with the frequency-controlled drive, the reduction of the number of units at the pumping stations does not reduce the operating possibilities of changing the modes of their operation caused by the change in the water flow rate.

Thus, the application of a frequency-controlled electric drive under certain conditions not only does not increase capital investments but also reduces them to some extent.

Calculations have shown that the application of a variable frequency drive in combination with an increase in unit capacity, depending on the purpose of the plant and other specific conditions, allows for reducing the reduced costs by 20-50%.

The sequence of feasibility study of variable frequency drive application in pumping units is given.

It is proved that the creation of energy-saving ACS in a pumping station based on the use of a variable frequency drive pays off in a sufficiently acceptable time even without taking into account water savings

VI. Conclusions

Depending on the calculated payback period of the ACS equipped with a variable frequency drive, a decision on the expediency of its use in the pumping station is made. At present, an acceptable payback period is considered to be 2-3 years. In any case, the payback period should not exceed the service life of the ACS equipment and the variable frequency drive, i.e. 10-11 years.

References

1. Khafizov I.I., Komil Gafforov, Bakhodir Oblokulov, Aziz Azimov Elimination of energy losses in pumping installations by means variable frequency drive, International Engineering Journal For Research & Development, Vol.5, Issue 3, April 2020, E-ISSN NO:-2349-0721, Impact factor: 6.03.P.83-89, http://iejrd.com/index.php/%20/article/view/17/5
2. Khafizov I.I., Komil Gafforov, Muxammedov Sh., Jurakulov A Energy saving when using a variable frequency drive in pump installations, Journal of Critical Reviews, ISSN- 2394-5125 Vol 7, Issue 12, 2020, P.99-102, http://dx.doi.org/10.31838/jcr.07.12.16
3. Khafizov I.I.,Khaitov B.B. The investigation of ions implantation processes into a single-crystal GaAs(001) to increase the efficiency of the solar cells, MODERN SCIENCE International scientific journal №02, 2017, Founder and publisher: “Strategic Studies Institute” LLC., Moscow, 2017, P.43-46
4. Khafizov I.I., Gafforov K.K. Application, and prospects of variable frequency means in electric drives of pumping units, Международный научно-практический электронный журнал «МОЯ ПРОФЕССИОНАЛЬНАЯ КАРЬЕРА» (ISSN 2658-7998, догоров с Elibrary №284-07/2019), 15.11.2020
5. Khafizov I.I., Xafizov X.I. Modeling the introduction of ions into single-crystal GaAs (001) to create p-n junctions to increase the efficiency of solar cells, МОЛОДЕЖНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ ПОТЕНЦИАЛ, Сборник статей II Международного научно-исследовательского конкурса, состоявшегося 11 января 2021 г. в г. Петрозаводске, ст.105-111
6. Н.Н.Садуллаев., А.Х.Шобоев., М.Б.Бозоров., А.Т.Паноев. Система мониторинга электропотребления предприятия на основе коэффициента эффективности системы электроснабжения. Europaische Fachhochschule. Volume: 08 / 2016. P.40-43. URL: https://www.elibrary.ru/item.asp?id=27542999 e- ISSN: 2195-2183
7. Н.Н.Садуллаев., А.Х.Шобоев., М.Б.Бозоров., А.Т.Паноев. Оценка эффективности системы электроснабжения методом многокритериального анализа. Europaische Fachhochschule. Volume: 08 / 2016. P.36-39. URL: https://www.elibrary.ru/item.asp?id=27542998 e- ISSN: 2195-2183
8. Н.Н.Садуллаев., М.Б.Бозоров., Ш.Н. Нематов. Контроль эффективности функционирования промышленной сети по обобщенному показателю

эффективности системы электроснабжения. Проблемы информатики и энергетики. Volume: 03 / 2018. P.57-62. URL: https://assets.uzsci.uz/edition/file/5e43dd733cce7.pdf#page=57

9. M.B. BOZOROV., I.I. XAFIZOV., J.M. ZOIROV., F.R. KAYIMOV., B.S. XAMDAMOV., D.A. ORIPOV., SHARIPOV A.SH. Forecasting electricity consumption of industrial enterprises using excel program. JournalNX- A Multidisciplinary Peer Reviewed Journal. Volume: 07 ISSUE 2 / 2021. P.346-350. URL: https://media.neliti.com/media/publications/342773-forecasting-electricity-consumption-of-i-ab0342bf.pdf e-ISSN: 2581-4230
10. Х.И.Хафизов., М.Б.Бозоров. Разработка метода комплексного исследования энергоэффективности системы электроснабжения промышленных предприятий. Сборник статей Международного научно-исследовательского конкурса. Петразаводск, Россия (2021). P.10-19. URL: http://is.nkzu.kz/publishings/%7BC1D6204A-6585-4F17-B6AD-E67180342C1C%7D.pdf#page=12
11. М.Б. Бозоров., И.И. Хафизов., А.Т. Паноев., Ж.М. Зоиров., Ш.К. Ергашев., Ф.Р. Кайимов., Б.С. Хамдамов., Д.А. Орипов., А.Ш. Шарипов. Разработка метода оценки эффективности системы электроснабжения промышленных предприятий. Сборник научных статей по итогам международной научной конференции. Казань (2021). P.42-45. URL: https://www.elibrary.ru/item.asp?id=44776698