CALCULATION OF ECONOMIC EFFICIENCY OF USING VARIABLE FREQUENCY DRIVE IN PUMPING UNITS IN UNDERGROUND LEACHING TECHNOLOGY OF MINERAL RESOURCES

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Abstract
The article discusses adequate assessment of the energy efficiency of using a variable frequency drive in pumping units in the technology of underground leaching of minerals, energy-efficient control methods, taking into account the specific features of the technology and design features of electric drives of pumping units used in the technology of underground leaching.

Keywords: Pump, energy saving, adjustable electric drive, energy efficiency, energy consumption, fictitious pressure.

Introduction

Submersible centrifugal pumps form a group that differs in design from conventional pumps with a horizontal shaft arrangement. The vertical arrangement of the pump in a well or borehole predetermined such design solutions as the perception of hydraulic load, the location and lubrication of bearings, the configuration and dimensions of the pump parts and their layout. [1]

One of the main directions in the field of energy saving is connected with the development and improvement of the electric drive (ED), which is the main consumer of electric power in industry . At present, ED consumes about 65% of all generated electric power. ED also accounts for the main part of the total losses of electric power in the power supply system of industrial enterprises (PE). For modern large PE, the losses of electric power in ED can reach 75% of the total losses in their power supply system. It follows that the main effect of energy saving can be obtained in the field of rational use of ED. [2]

DISCUSSION OF THE PROBLEM

Of all the electric power consumed by EP, approximately 90% is accounted for by the simplest unregulated EP and 10% by regulated EP. Theoretical studies and operating experience show that replacing unregulated EP with regulated EP can provide significant economic and technical effects - savings of 10% or more of the electricity produced in the country, savings of fresh water, natural gas, etc. Basically, a mass transition to regulated EP is expected in AC electric drive systems due to the use of frequency converters. [3]

The energy efficiency assessment of the use of a variable frequency drive in pumping units in the technology of underground leaching of minerals is carried out in stages:

Stage 1. Energy consumption is determined W_1 under existing operating conditions and the existing control system using instrumental means or by calculation;

Stage 2. Energy consumption is determined W_2 when implementing a variable frequency drive, usually by calculation or by processing statistical data on specific indicators;

Stage 3. Energy savings ΔW in kind are determined when implementing a variable-frequency electric drive;

Stage 4. Assessment of energy efficiency $Э_{ТЭР}$ in monetary terms;

Stage 5. Calculation of the payback period. [4]

In the first stage of calculation, energy consumption is determined **under** existing operating conditions and the existing control system. It is preferable to determine using instrumental means that allow obtaining more accurate data compared to the calculated values. However, there are a number of pumping units for which, for one reason or another, it is impossible to use instrumental means. In this case, it becomes necessary to use calculation methods.

The calculation of the power consumption of a pumping unit with **an unregulated** electric drive is determined as:

$W_{сум} = P_p \cdot КИО \cdot t$, kW*h

where: K_u **- power utilization factor (for pumping units it is taken as 0.7-0.8) [4];**

$КИО$ **- equipment utilization factor by time (in the absence of data, it is taken as 0.8-0.9 for pumping equipment in the technology of underground leaching of minerals);**

t - duration of the billing period, hours/year;

P_p **- the estimated power of the pumping unit at a known current is determined:**

$P_p = \sqrt{3} \cdot I_ф \cdot U \cdot \cos\varphi$

where: $I_ф$ **- phase current is determined on the basis of instrumental measurements at the average pumping unit capacity** $Q_{ср}$ **(m3 / h) . Average performance , set using the existing pump performance control system.**

Average productivity $Q_{ср}$ (m3 / h) for the calculation period is determined in accordance with the feed schedule. Expert assessment is possible $Q_{ср}$ if statistical data on changes in pump feed are available. The simplest method of determination $Q_{ср}$ is based on statistical data on annual productivity and pump operating time at the relevant wells, reservoirs, etc. [5]

In the second stage of calculation to determine energy consumption W_2 when implementing **a variable frequency drive,** it is necessary:

1.Determination of the nominal parameters of the pumping unit:

1.1. Determine the nominal parameters of the pump according to the passport:

- passport feed – $Q_{ном}$, m3 / s.;

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- passport pressure – $H_{ном}$, m;

- passport efficiency of the pump – $\eta_{ном}$.

1.2. Determine the passport data for the drive electric motor:

- rated power – $P_{ном}$, kW;

- nominal voltage – $U_{ном}$, V;

- nominal rotation speed – $n_{ном}$, rpm;

- nominal engine efficiency – $\eta_{дв}$;

- nominal engine efficiency – $\eta_{пч}$;

- nominal power factor – $\cos\varphi_{ном}$;

1.3. Additional data required for calculation:

- density of the pumped liquid – $\rho_{н,к}$ kg/ m3;

- average productivity (determined in the first stage of calculation) $Q_{ср}$ (m3 / h) = $Q_{ср}$, m3 / s.

2. In accordance with the average performance of the pumping unit, the consumed electrical energy is calculated W_2 in the frequency regulation mode of the pump feed. [6]

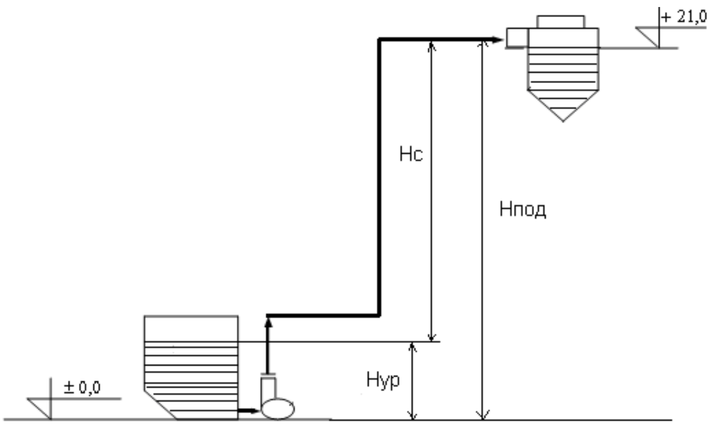
The average value of the angular velocity of the pump during delivery is determined $Q_{ср}$

$$\omega_{ср} = \omega_{ном} \cdot \sqrt{\frac{H_c}{H_ф} + \left(1 - \frac{H_c}{H_ф}\right) \cdot \left(\frac{Q_{ср}}{Q_{ном}}\right)^2}, \text{s}^{-1},$$

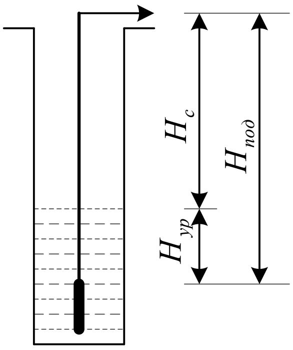
where $\omega_{ном}$ is the nominal angular speed of the pump, s $^{-1}$

$$\omega_{ном} = \frac{\pi n}{30}, \text{ s}^{-1};$$

H_c - static pressure, defined as the difference in geodetic marks between the liquid surface and the highest level of liquid supply, m (meters of water column), (Fig. 1 a, b); $H_ф$ - fictitious pump pressure, m; $Q_{ном}$ - nominal (passport) pump flow, m3 / s.



a – flow chart of concentrate pumping from the sump



b - diagram of a well with a submersible pump

Fig. 1. Schematic diagram of liquid pumping using pumping units

If pumping is not pure water, but liquid in the form of pulp (with a high content of solid particles), concentrate, etc., then the static pressure should be recalculated using the formula

$$H_{с.пульпы} = H_c \cdot \frac{\rho_{н,к}}{\rho_в}, \text{m}$$

where $\rho_{н,к}$ is the density of the pumped liquid (pulp, concentrate, etc.), kg/m3 ; is $\rho_в$ the density of water, 1000 kg/ m3 .

The fictitious pressure is determined by the formula $H_ф = (1{,}25 - 1{,}45) \cdot H_{ном}$, where $H_{ном}$ is the nominal (passport) pressure of the pump. The coefficient 1.25 should be taken for clean water pumps, the coefficient 1.45 – for pumps for pumping pulp or concentrate, etc.

The average value of the pressure developed by the pump is determined depending on the average value of the angular velocity [7]

$$H_{ср} = H_c + (H_{ном} - H_c) \cdot \frac{H_ф \cdot \left(\frac{\omega_{ср}}{\omega_{ном}}\right)^2 - H_c}{H_ф - H_c}, \text{ m.}$$

This relationship is valid if the pump is selected correctly and the pipeline is designed so that at the nominal speed the nominal flow and pressure are ensured.

The efficiency of the pump is determined at the average value of the angular velocity

$$\eta_н = 1 - \frac{1 - \eta_{ном}}{\left(\frac{\omega_{ср}}{\omega_{ном}}\right)^{0,36}},$$

where is $\eta_{ном}$ the nominal (passport) efficiency of the pump.

RESULTS OF DISCUSSION

The electrical energy consumed by the pumping unit, with frequency regulation at average capacity and average pressure, is determined by the expression

$$W_2 = \frac{\rho_{н,к} \cdot Q_{ср} \cdot H_{ср}}{102 \cdot \eta_н \cdot \eta_{дв} \cdot \eta_{пч}} \cdot t \cdot КИО, \text{ kW*hour,}$$

This expression is valid for pumping units in which there is no resistance of the medium (for example, resin on sorption columns) to the movement of the pumping liquid.

where: $КИО$ - equipment utilization factor by time (in the absence of data, it is taken for pumping equipment in the technology of underground leaching of minerals as equal to 0.8-0.9; [8]

t - duration of the billing period, hours/year;

$\eta_{н}$ -Pump efficiency;

$\eta_{дв}$ - engine efficiency;

$\eta_{пч}$ Efficiency of frequency converter.

In the third stage of calculation energy savings in kind are determined when implementing a variable frequency drive

$\Delta W = W_1 - W_2$, kW*hour.

In the fourth stage of the calculation, energy efficiency is determined in monetary terms.

$Э_{ТЭР} = Ц_{ТЭР} \cdot \Delta W$, million soums /year,

where $Ц_{ТЭР}$ is the energy tariff (sum/kWh).

In the fifth stage we calculate the simple payback period

$$T_{ок} = \frac{Э_{чп}}{Э_{ТЭР}}$$, year

where: $T_{ок}$ - payback period; $Э_{пч}$ - cost of the frequency converter with transportation (delivery) and commissioning costs.

CONCLUSION

When deciding on the advisability of implementing a variable frequency drive, it should be taken into account that in addition to the economic effect of saving electricity, the use of a variable frequency drive also provides the following:

- ✓ the valves are fully open most of the time ;
- ✓ Most of the time, the pumps operate at reduced pressures, which reduces leaks in the system;
- ✓ The wear of switching equipment is reduced, since its switching occurs in the absence of current;
- ✓ Reduces wear on engine and pump bearings, as well as the impeller, due to the smooth change in the number of revolutions;
- ✓ There are no large starting currents;
- ✓ The risk of accidents is reduced by eliminating hydraulic shocks;
- ✓ Provides simultaneous protection of the motor from short-circuit currents, ground faults, overload currents, open-phase mode, and unacceptable overvoltages;

✓ The possibility of further comprehensive automation of water supply system facilities appears.

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