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Efficient use of electric pumping units

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ABSTRACT: This article discusses the issues of efficient use of an electric drive on pumping units. Applications of an automated electric drive for pumping units.Increasing the efficiency of the pumping units due to the reliable adjustable electric drive with smooth regulation of the operating parameters of the pumping unit without unnecessary energy consumption with ample opportunities to increase the efficiency of the water supply systems.

KEYWORDS: Electric drive, pump, automation, feedback, efficiency, electricity, power, voltage, frequency, start-up, operation, piping, regulation, control.

I. INTRODUCTION

Saving water, its rational use is extremely important for the steppe territories of Uzbekistan, as well as for hilly areas. The conservation of electrical energy is an important part of the overall trend towards environmental protection. Getting a ton of fuel and generating the appropriate amount of energy is about twice as expensive as saving. Electric motors that drive systems in everyday life and in production, consume more than 60% of the energy produced, it is here that the largest reserves of energy conservation are laid.
The conservation of electrical energy is an important part of the overall trend towards environmental protection. Getting a ton of fuel and generating the appropriate amount of energy is about twice as expensive as saving. Electric motors that drive systems in everyday life and at work consume more than 60% of the energy produced, it is here that the largest reserves of energy conservation are laid.
In Uzbekistan, pumping units are one of the main consumers of electric energy. Pumping installations are used in all sectors of the economy. For example, about 30% of the energy consumed for agricultural needs in which one of the main consumers are electric drives of pumping units. Payment of electricity consumption of electric drives of pumping units of agriculture is made at the expense of budgetary funds. Therefore, the efficient use of electric pumping units is the main task.

II. SIGNIFICANCE OF SYSTEM

Pumping units can be conditionally divided into three large groups: powerful (more than 500 kW) units of power facilities; industrial units and centralized water supply pumping stations (50-300kW); mass installations (2-50 kW), which include pumps with a feed of 12-100m3 / h and a pressure of 20-80m.v.st.
In the first group, due to its specificity, progressive types of electric drive are used. In the second and especially in the third, most massive, up to now, an unregulated electric drive with asynchronous squirrel-cage motors has prevailed, and performance control is carried out in an extremely inefficient way - throttled. This does not allow for a rational energy consumption and flow rate of water, steam, air, etc. when changing technological needs over a wide range.
A typical example of such mechanisms are pumping stations for cold and hot water supply and heating systems for residential and industrial buildings. Selected based on maximum performance, these mechanisms work most of the time with lower performance. According to some reports, the average daily load of cold water pumps is only 50-55% of the maximum. Existing water supply systems do not provide a noticeable reduction in power consumption with a decrease in consumption, and also cause a significant increase in pressure (pressure) in the system, which leads to water leaks and adversely affects the operation of technological equipment and water supply networks.
Ways to increase the efficiency of pumping units: increasing the efficiency of pumps and pipelines; regulation of plant performance; streamlining the schedule of plant loads; organizational activities.
Increasing the efficiency of the pumps is ensured by careful balancing of the impellers, regular replacement of seals, and ensuring the operating point of the pump in the zone of maximum efficiency.

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Improving the efficiency of the pipeline can be due to:
• increasing the cross section of pipes;
• inclusion in parallel operation of a backup discharge head;
• reducing the length of the pipeline;
• regular cleaning of the pipeline;
• elimination of excessive fittings and unnecessary turns in the pipeline or reduction of their resistance by smoothing sharp corners;
• the use of fittings with lower values of the coefficient of local resistance (for example, replacing poppet valves with ball valves in suction pipelines).

Traditional methods of regulating the supply of pumping units consist in throttling the pressure lines of the pumps and changing the total number of operating units according to one of the technological parameters - pressure on the manifold or at the dictating point of the network, level in the receiving or regulating tank, etc. These methods of regulation are aimed at solving technological problems and practically do not take into account the energy aspects of water transport. With this regulation, from 5 to 15%, and in some cases up to 25-30% of the consumed electricity, is wasted irrationally due to:
• energy losses in the throttle body;
• creating excess pressure in the pipeline network;
• leaks and unproductive expenses of water in the network and at the consumer;
• increase in geometric lift during pumping of water from reservoirs of sewage pumping stations, etc.

Consequently, with the advent of a reliable controlled electric drive, prerequisites have been created for creating a fundamentally new technology for water transport with smooth regulation of the operating parameters of a pumping unit without unproductive energy costs with wide opportunities to increase the efficiency of water supply systems. At the same time, the characteristics of pipelines, and not the characteristics of the pumps, as in the case of regulating the supply of pumping units with a constant speed, become the geometric place of the operating points of the pump installation.

III. METHODOLOGY

Advantages of the electric drive in comparison with other types of drives:
• a simple method of electric power transmission;
• high efficiency;
• work without waste;
• The drive is adjustable and reversible.

Most electric motors operate in unregulated mode and, therefore, with low efficiency. Due to deficiencies in the design and operation of the electric drive, the load factor of many machines does not exceed 50%, which dictates the need to reduce the installed power of the engines.

Induction motoris regulated by changing the following parameters:
• network (voltage, frequency);
• motor (number of pole pairs, inductance, rotor resistance).

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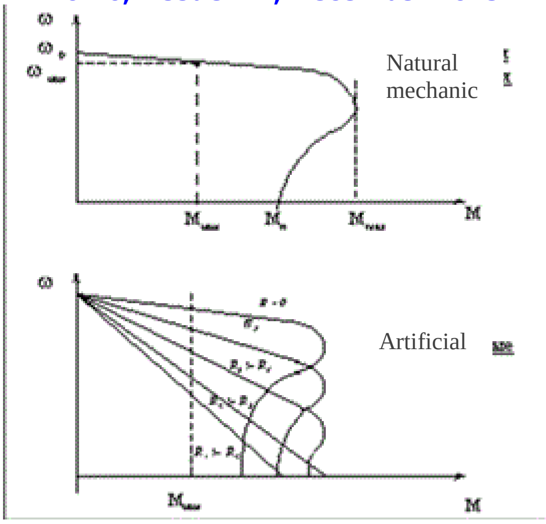

Fig. 1. Natural and artificial mechanical characteristics of an induction motor

The natural mechanical characteristic of an induction motor takes the form of a curve, as shown in the figure. The working part of the characteristic is rigid. Depending on the resistance, the rotor circuit in induction motors with a phase rotor has a family of artificial characteristics (ω0=const, Δωk≡R, Mk=const). Moreover, the greater the resistance of the rotor circuit, the softer the characteristic (with a shorted rotor R = 0 a natural characteristic).
Due to its simplicity, rheostatic regulation was widely used in hoisting-and-transport devices. Disadvantages: step change in speed, low speed, high energy loss.
The interaction of the magnetizing forces of the stator and rotor is possible only with the same number of pairs of poles of their windings. Therefore, the regulation of the number of pole pairs is applicable only to AM with a squirrel-cage rotor, the rotor winding of which automatically forms the same number of pole pairs as the stator winding. Two-speed motors are manufactured both with two independent stator windings, and single-winding with windings sectioning.

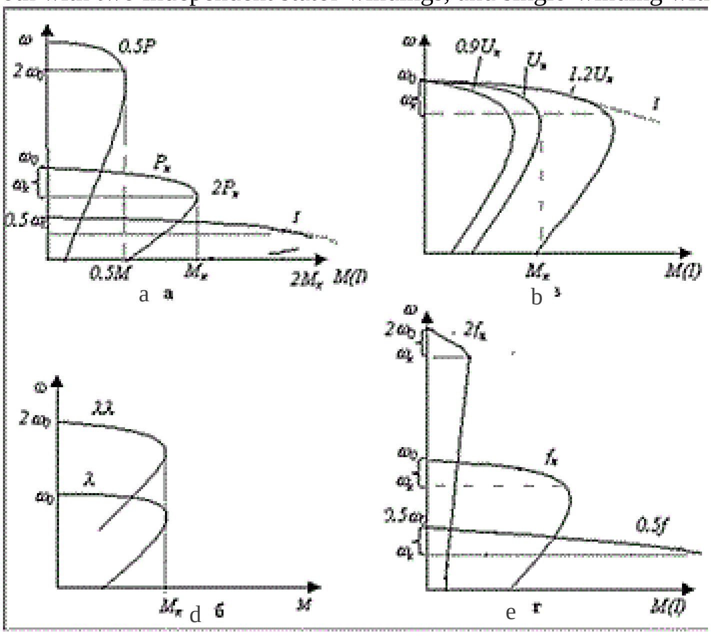

Fig. 2. Schedule the regulation of Induction motorby the inclusion of additional inductance in the stator circuit
In the first case (Fig. a), the engine has increased dimensions, low efficiency and power factor, a lot of unused copper (ω0≡1/p,Δωk≡1/p, Mk≡p).

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Most simply switch the number of pole pairs in the ratio of 1: 2. For this, the winding of each phase is made of two sections. When the current direction changes in one of them, the number of pole pairs changes. Typically, stator windings are switched from a star to a double star, or from a triangle to a double star. The transition to a double star is accompanied by a two-fold decrease in the number of pole pairs, i.e., a twofold increase in speed. In this case, the overload capacity remains constant.
The regulation of the ABP speed by the inclusion of additional inductance in the stator circuit is carried out due to the redistribution of voltage between them (ω0=const, Δωk≡1/Lk, Mk≡1/Lk). Due to the small range of regulation and reduction of overload capacity, it is almost not applied in practice.
Speed regulation by changing the voltage affects the electromechanical properties of IM(ω0=const, Δωk=const, Mk≡U2). With a decrease in voltage, the overload capacity of the motor sharply decreases (at U = 0.9Uн, the critical moment decreases by 19%), with an increase, the current increases and the heating of the stator winding increases (Fig. c). Therefore, regulation is possible in a small range.
The speed of induction motors is proportional to the frequency of the supply voltage. Thus, a change in the engine speed can be achieved by changing the frequency of the consumed voltage. On the other hand, the engine torque is proportional to the magnetic flux in the air gap of the engine. The latter, in turn, is proportional to the supply voltage and inversely proportional to the frequency of the supply voltage. Thus, the motor torque can be changed by adjusting the supply voltage to any desired frequency.
To obtain a constant moment of induction motors at varying speeds, it is necessary to have an energy source with adjustable voltage and frequency, which will maintain a constant ratio U / f = const, where U is the voltage of the supply network; f is the frequency.
The most famous way to get this type of energy is to convert an alternating current at an industrial frequency of 50 Hz to direct current using a rectifier, and then back to alternating current using an inverter. In this circuit, the voltage is regulated by a rectifier, and the frequency by an inverter
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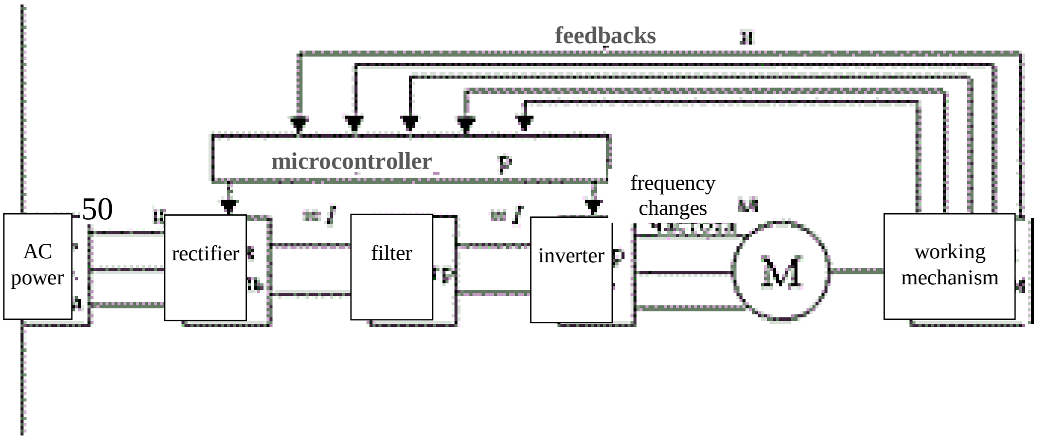

Fig. 3. Functional diagram of a variable frequency drive

The main elements of a variable frequency drive are a rectifier, an inverter, an asynchronous or synchronous motor, a programmable microcontroller. In addition to the above, inductances and /or capacitors are used to stabilize the output of the rectifier and minimize the level of higher harmonics.
When a large inductance is connected in series with the output of the rectifier, such a system is called a current inverter. When a large capacity is connected in parallel with the output of the rectifier, it is a voltage inverter.
In addition, pulse width modulation (PWM) is used. In this circuit, an uncontrolled rectifier is used, and an alternating current with an adjustable frequency and an adjustable voltage level is generated by the inverter. PWM reduces the harmonic content at the inverter output by improving the current waveform of the current inverter or the voltage shape at the voltage inverter output.
The frequency control method provides:
• smooth regulation of engine speed in a wide range on both sides of the nominal;
• tough artificial characteristics;
• continuous overload capacity.

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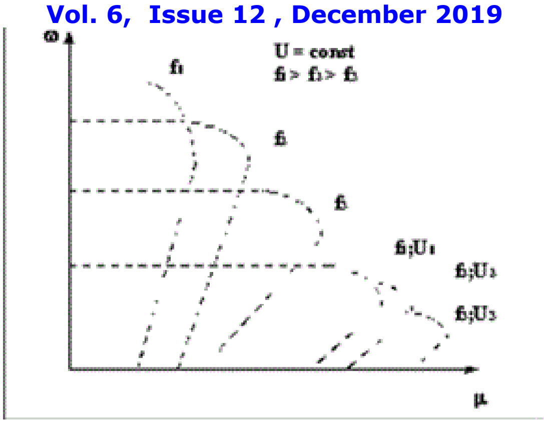

Fig. 5. Frequency control method

To ensure the required engine characteristics simultaneously with the frequency change, it is necessary to change the value of the supply voltage, depending on the nature of the load change:

- lift load

$$M_c = const;\ U/f = const;$$

$$M_c \equiv n^2 \equiv f^2;\ U/f^2 = const;$$

- traction load

$$M_c \equiv 1/n \equiv 1/f;\ U/\sqrt{f} = const;$$

- linear load

$$M_c \equiv n \equiv f;\ U/\sqrt{f^3} = const.$$

In addition, electric drives with direct frequency conversion are used, they have several advantages:
• a single conversion of energy and, hence, high efficiency;
• free exchange of reactive and active energy from the network to the engine and vice versa;
• lack of switching capacitors.

The control system includes: a universal technological variable controller, as well as a control action generator based on a real-time clock. This solution allows you to maintain the pressure in the pipeline at a predetermined, in accordance with the daily routine, level exclusively by means of an electric drive, without the use of industrial controllers.

IV. EXPEREMENTAL RESULTS

To quantify the energy and water savings when introducing a controlled electric drive, a frequency-controlled electric drive was installed at one of the booster pump stations for cold water supply in residential buildings, ensuring a constant pressure at the pump outlet regardless of flow, and the pressure at the inlet and outlet of the pump station was recorded and measured electricity and water consumption when working in unregulated and adjustable modes. A pump with a nominal flow of 100 m^3 / h and a pressure of 32 m was driven into rotation by an 15 kW induction motor. The measurements showed that over the year, energy savings are 45,457 kWh (40.5%), and water savings are 114,135 m3 (25%).
When the economic effect is only due to energy savings, the cost of electrical equipment to control the speed of the electric motor pays for itself in a year of operation.
Preliminary calculations show that with the widespread introduction of variable frequency drives, you can save 7-10% of the generated electricity.
The speed of the induction motor is proportional to the frequency of the supply network (ω0≡f, Δωk=const, Mk≡1/f2).With increasing frequency, the speed increases, the critical moment decreases, and the corresponding speed drop remains constant. With decreasing frequency, the overload capacity increases, however, the current increases, that is, heating the motor.

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If the voltage and frequency of the motor are changed according to the frequency law U / f = const, then the magnetic flux and critical moment of the motor remain (ω0≡f, Δωk=const, Mk=const). Regulation is possible over a wide range with constant stringency.
Induction motors are used in almost all types of installations, while in most cases squirrel-cage induction motors are widely used.
With an increase in engine power, its nominal value of efficiency and power factor increases, the actual values of which, depending on the engine load factor, are approximately estimated by the table.

Load factor, $k_з$	Efficiency, η	Power factor, cos φ
0,1	0,48	0,34
0,2	0,68	0,56
0,3	0,79	0,70
0,4	0,86	0,79
0,5	0,93	0,87
0,6	0.97	0,93
0,7	1,0	0,97
0,8	1,01	1,0
0,9	1,01	1,0
1	1,0	1,0

Low-power engines are characterized by a disproportionate large unit cost (cost 1 kW) compared to large electric motors. The graph shows that the unit cost ceases to change significantly with engine powers above 60 kW.
Engines with a power below 200 kW usually have a voltage of 380 V, more than 300 kW with 6 (10) kV, and motors with a power of 200 - 300 kW have a voltage of either 380 V or 6 (10) kV.
Capital costs are taken into account primarily when deciding to purchase an engine, but taking into account the life of the electric motor, operating costs (the cost of electricity and maintenance consumed) are an order of magnitude or more higher than capital.

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