INCREASING THE ENERGY EFFICIENCY OF THE EQUIPMENT IN THE MACHINE HALL OF THE 478 MW STEAM-GAS TURBINE AT NAVOI THERMAL POWER PLANT

Boboniyozov Qutbiddin Asliddin o'g'li
Pulatov Abror Obidovich
Umarov Shuxrat Badreddinovich
Tashkent State Technical University, Tashkent, Uzbekistan

qutbiddinboboniyozov@gmail.com

Abstract. The optimization of pump units and their control systems, as well as increasing energy efficiency through the implementation of digital and automated control methods. The research investigates mathematical modeling of electromechanical systems, organizing effective control using frequency converters, and ways to reduce energy consumption. The dissertation proposes innovative approaches aimed at achieving high efficiency, improving reliability, and significantly reducing electricity consumption in water lifting processes.

Keywords: power plant, power, pump, water, frequency, drive, asynchronous, energy efficiency.

INTRODUCTION

Currently, Uzbekistan is on the path of development in all sectors of the economy, and consequently, the demand for electricity is steadily increasing. In particular, electricity consumption is growing not only in small-scale production but also in all large industrial facilities. One of the significant challenges is supplying energy to the population and providing electricity to large manufacturing plants. Therefore, organizing the efficient operation of pump motors is a pressing issue.

Optimizing and effectively managing the operating modes of pumping units and their associated pumps, as well as transitioning them to digital control, including computer control, is a crucial task in managing the technological process of water lifting. This issue is at the center of attention for specialists focused on improving production quality and automating pump operating modes to ensure water use schedules.

Processes in water supply systems and pumping units are controlled and implemented in various ways according to the requirements of the complex water lifting technological process.

The purpose of this work is to develop methods for increasing controllability, reliability, and energy efficiency, as well as to develop means, methods, and approaches for optimal influence on the electromechanical systems of pumping mechanisms and units.

The research is based on the theory of mathematical modeling of electromechanical energy converters and the theory of digital control.

Modern MATLAB and MATHCAD software are used as the mathematical tools.

The main tool for theoretical research of energy-efficient operating modes of pump electric drives is a mathematical model describing transient processes in an electromechanical system under effective digital control.

NAVOI THERMAL POWER PLANTS: GENERAL INFORMATION

The open joint-stock company "Navoi Thermal Power Plant" is the main source of heat and electricity supply for industrial and socio-cultural facilities in the region.

The 478 MW Navoi Thermal Power Plant is located in the Karmana district of Navoi city. The power plant is designed for uninterrupted power supply. It operates on the basis of a combined cycle gas turbine unit.

In general, a large number of electric motors are used at the power plant. However, we will analyze only the motors in the machine hall that serve the plant's own needs and contribute to the normal operation of the combined cycle gas turbine. The table below lists some of the units.

Table 1.

No	Name and type of units	P_{rated} kW	category	*Cosφ*
1.	Water supply pump AECW-S2	3050	1	0.9
2.	Water supply pump AECW-S2	3050	1	0.9

3.	Circulating water pump HRQ3509-16Y	850	1	0.85
4.	Circulating water pump HRQ3509-16Y	850	1	0.85
5.	Condensate pump AEJG-PA	280	1	0.88
6.	Condensate pump AEJG-PA	280	1	0.88
7.	Closed-loop cooling pump AMI 400L6A VA1	400	1	0.8
8.	Closed-loop cooling pump AMI 400L6A VA1	400	1	0.8
9.	Cooling tower fan 0.4 kV M3BP355SMA4	245	1	0.87

DETERMINING THE TECHNOLOGICAL PARAMETERS OF THE POWER PLANT

Design parameters include the nominal pump capacity $_{(Qn)}$ and pressure (H), the layout of pressure pipes (simple or complex piping), the nominal power and rotational speed of the drive motors, the power of transformers, the nominal voltage of the equipment, and others. If they are operated at the specified nominal values of the mode parameters, these are not controlled.

Technological parameters include $_{NS}$ water level at the intake structure (Δn), technological graph coverage of water supply (Qt = $_{Qn)}$ and others.

Examples of electrical parameters include voltage values at motor terminals (U_c), active and reactive power (P, Q), load factor (γ_3), energy indicators (ŋ, cosφ), and so on.

Thus, in the absence of static pressure, the moment of resistance is proportional to the square of the angular velocity. In this case, of course, the power is proportional to the cube of the velocity. In the general case, when $Hst = const \neq 0$, the dependence of Mst on ω is calculated from the intersection points of the main characteristic with the Q-N characteristics, the coordinates of which are substituted into the formula. This method of determining the dependence of Mst on ω does not provide its analytical expression. However, in the range of change of the resistance moment from MST,min to MST,max, using parabolic approximation for the function Mst (ω), it is possible to find an approximate analytical expression:

$$M_{st} = M_{st,\max}\left(\frac{\omega}{\omega_{st,\max}}\right)^{k}$$

Knowing $M_{ST,\min}$ and $M_{ST,\max}$ and the corresponding minimum and maximum velocities $\omega_{CT,\max,}$ we determine the parabola exponent k:

$$K = \frac{\lg \dfrac{M_{st,\min}}{M_{st,\max}}}{\lg \dfrac{\omega_{st,\min}}{\omega_{st,\max}}}$$

For centrifugal type mechanisms, the mechanical properties corresponding to the formulas in cases where $_{Nst} = 0$ and $_{HST} = const \neq 0$ are depicted by dashed lines. Taking into account mechanical losses due to friction, the actual properties are indicated by continuous lines.

AUTOMATED FREQUENCY-CONTROLLED ASYNCHRONOUS ELECTRIC DRIVE

Asynchronous electric motors are one of the most widely used types of electric machines. They are manufactured with power outputs ranging from 0.1 kW to several thousand kW and are extensively utilized across various fields and industries. The main advantages of these motors are their simple design and relatively low cost. However, due to their operating principle, it is impossible to control the rotational speed of these motors using a basic connection scheme. Particularly, to significantly reduce energy consumption and prevent overheating of the rotor in asynchronous motors with a short-circuit rotor, the motor must operate in a long-term mode with minimal slip values. Let's examine the existing methods for controlling the rotational speed of asynchronous motors. The motor's rotational speed depends on two factors: the rotational speed of the electromagnetic field in the stator ω0 and the slip coefficient S.

$$\omega = \omega_0 - S_{abs.}.$$

$$\omega = \omega_0 \cdot S.$$

The use of a frequency converter in a pump ensures savings of 7-8% of the total electricity consumption.

Stromberg company's frequency converters are highly reliable and sufficiently compact means of controlling pump units. To ensure uniform operation of pump units, a device is provided that allows them to be connected alternately to a single converter.

Since the pumping unit is designed for water supply, i.e., continuous water provision, special requirements are imposed on the electric drive: the motor must start smoothly and stop gradually; the speed control range must be at least 2:1; there must be strict feedback on speed; feedback on water consumption is necessary.

FREQUENCY START-UP OF AN ASYNCHRONOUS MOTOR.

According to the research conducted at the site, from an energy perspective, the "soft" start-up mode is of practical interest ($<_{KR}$)

For a pump's electric drive, a uniform change in speed during start-up is very important, as it positively affects its operating mode.

Let's define the "soft" start-up limit.

$$\varepsilon_{KR} = \frac{M_{Max} - M_{ST}}{J_{\sum} \cdot \omega_{1N} \cdot (1 - s_N)}$$

After substituting the corresponding variables, we obtain $_{KR=22}$ Hz/s.

Let's adopt a smoother start: = 8 Hz/s or 46 rad/s. The time for frequency to increase to the nominal value (50 Hz) is tP=6.3 seconds

We can determine the motor speed using the following formula:

$$\omega = \varepsilon \cdot (t - T_M) \cdot (1 - e^{-\frac{t}{T_M}})$$

After the frequency reaches 50 Hz, the motor's acceleration is expressed by a different equation

$$\omega = \omega_{TUG} - (\omega_{TUG} - \omega_{BOSH}) \cdot e^{-\frac{t}{T_m}}$$

and ends after 3.4Tm, i.e., the start-up transition process takes 38 seconds.

The graph of the transient process of starting the pump's asynchronous motor to the nominal speed is presented.

Indicators of energy efficiency changes during the operation of the pumping unit under optimal control for the pumping unit

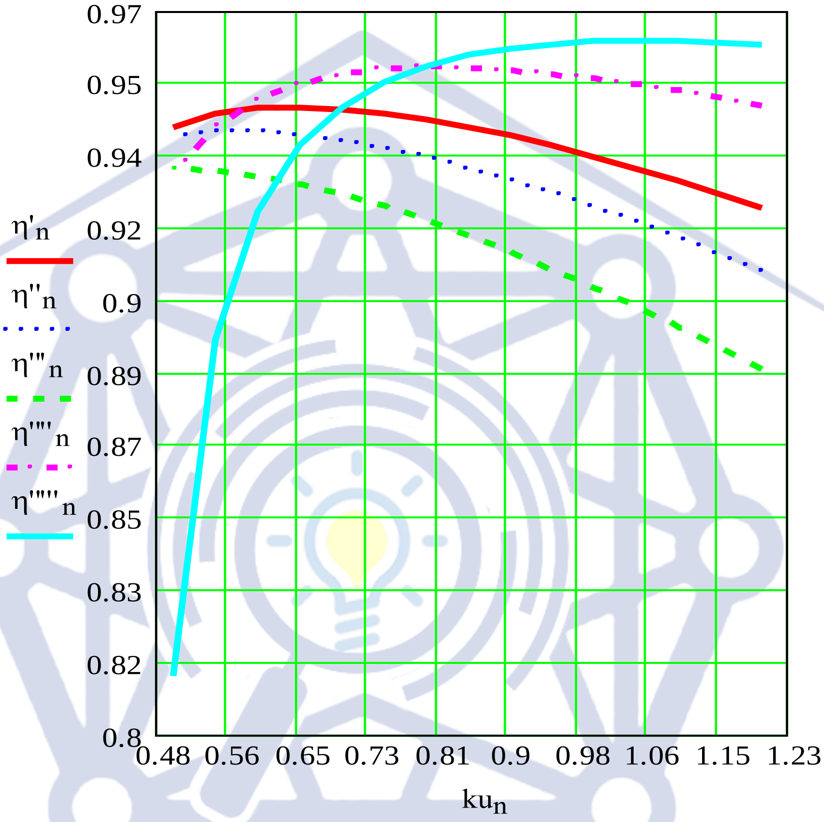

Figure 1. Indicators of changes in energy efficiency during the operation of a pumping unit with optimal control (efficiency)

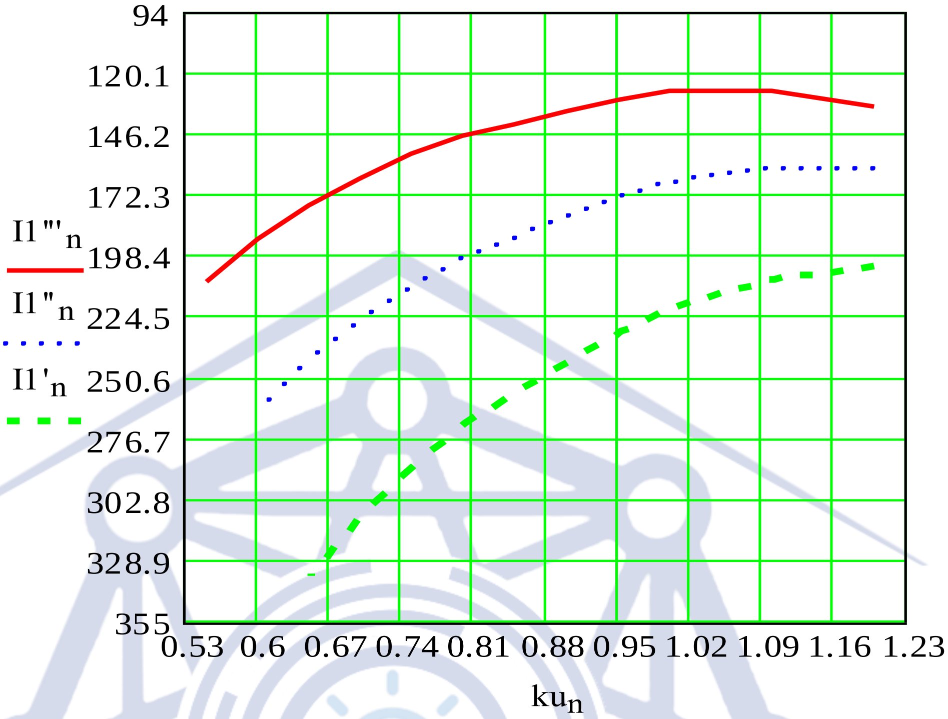

Figure 2. Indicators of changes in energy efficiency during the operation of the pumping unit under optimal control (stator current)

Indicators of changes in energy efficiency under optimal control of the pumping unit

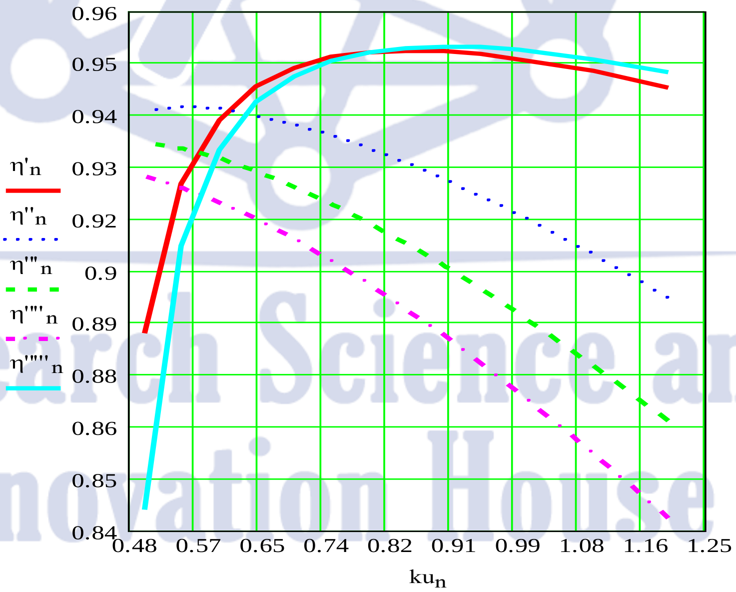

Figure 3. Indicators of changes in energy efficiency (efficiency) under optimal control of the pumping unit

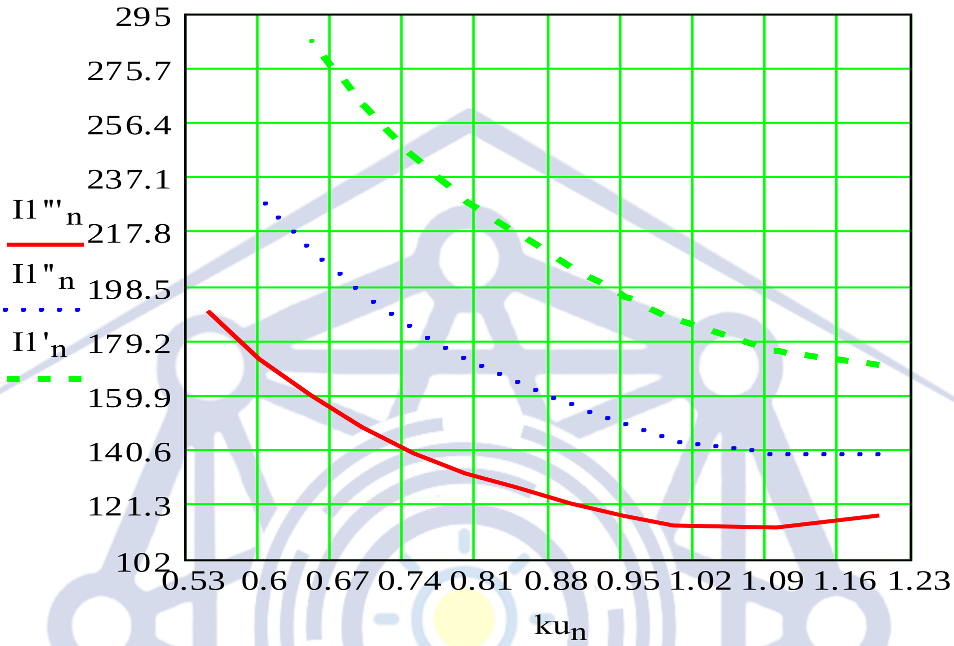

Figure 4. Indicators of changes in energy efficiency under optimal control of the pumping unit (stator current)

CONCLUSION

The relevance of this work is related to the need for modernizing existing asynchronous electric drives, aimed at improving the energy efficiency and managing the performance of electrical equipment in pumping stations during low-load operating modes on the motor shaft. These operating modes are directly linked to the technological characteristics of water lifting or load changes, as well as significant improvements in the processes of starting the pump and regulating its productivity.

As a result of the work carried out on the development and study of energy-saving operating modes, taking into account the load characteristics and water lifting patterns of asynchronous electric drives for pumps, the following conclusions were drawn:

1. Based on the analysis of literature on water schedules, existing energy-saving technologies and electric drive systems for installed power and pumping

mechanisms and their operating modes, the feasibility of researching energy-saving systems for variable-speed and fixed-speed electric drives has been proven.

2. A method for calculating and determining the optimal voltage values for electrical equipment based on the degree of load is proposed.

3. Structures and connection diagrams of microprocessor-controlled energy-saving asynchronous electric drives have been developed, ensuring an increase in energy efficiency indicators in the load function.

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