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Energy Saving in the Operation of Electric Motors

Pardaboyev Abdurahim

Faculty of Electro mechanics and Radio electronics,
Jizzakh polytechnic institute,
Jizzakh city, Uzbekistan
Uchqun8822@gmail.com

***Abstract**-The article considers the possibility of an optimal solution for the operation of electric machines. It shows the ways to ensure energy saving by reducing losses in transient modes and in steady-state operation.*

Keywords: industrial enterprises, Energy losses, electrical circuits, electric drive.

Introduction

Currently, industrial enterprises should develop measures to save electricity in relation to each electrical installation. First of all, this applies to Electromechanical devices with an electric drive, the main element of which is an electric motor. It is known that more than half of all electricity produced in the world is consumed by electric motors in the electric drives of working machines, mechanisms, and vehicles. Therefore, measures to save electricity in electric drives are most relevant.

The problems of energy saving require optimal solutions not only in the operation of electric machines, but also in their design. In particular, it concerns the reduction of energy losses in transient regimes and in the first turn when starting it up.

Energy losses in transient modes can be significantly reduced by using engines with lower values of rotor moments of inertia, which is achieved by reducing the diameter of the rotor while increasing its length, since the engine power must remain unchanged.

An effective means of reducing losses when starting engines is starting with a gradual increase in the voltage supplied to the stator winding. The braking mode of mechanisms should also be implemented taking into account the requirements of energy conservation, since the energy released when the engine is decelerated is equal to the kinetic energy stored in the moving parts of the electric drive when it is started.

The energy-saving effect of braking depends on the method of braking. The greatest energy-saving effect is provided by generator regenerative braking with energy return to the grid.

The greatest energy losses are observed when braking by counterclockwise switching, when the energy consumption is equal to three times the value of the energy dissipated in the engine during dynamic braking. An effective means of energy saving in this case is to reduce the voltage supplied to the engine during periods of its operation with underloading.

If the drive is an asynchronous motor that operates when connecting the stator windings with a triangle, the reduction of the voltage supplied to the phase windings can easily be realized by switching these windings to the star connection star, since in this case the phase voltage is reduced by 1.73 times.

When designing an electric drive, the correct choice of motor power is important. Thus, the choice of an engine with an inflated rated power leads to a decrease in its technical and economic indicators (efficiency and power factor), caused by under loading the engine. This decision when choosing an engine leads to both an increase in capital investment (with increasing power, the cost of the engine increases) and operating costs, since with a decrease in efficiency and power factor, losses increase, and, consequently, unproductive electricity consumption increases. The use of engines with low rated power causes them to overload during operation. As a result, the overheating temperature of the windings increases, which contributes to an increase in losses and shortens the service life of the engine. Eventually, accidents and unexpected stops of the electric drive occur and, consequently, operating costs increase. This is particularly true for DC motors due to the presence of an overload-sensitive brush-collector Assembly.

A rational choice of start-up and control equipment is of great importance. On the one hand, it is desirable that the processes of starting, braking reverse and speed control are not accompanied by significant losses of electricity, since this leads to an increase in the cost of operating the electric drive. But, on the other hand, it is desirable that the cost of start-up devices would not be extremely high, which would lead to an increase in capital investment.

The solution of the problem of energy saving is facilitated by the use of synchronous motors that create reactive currents in the supply network that are ahead of the voltage phase. As a result, the network is unloaded from the reactive (inductive) component of the current, the power factor on this section of the network increases, which leads to a decrease in the current in this network and, as a result, to energy conservation. The same goals are served by the inclusion of synchronous compensators in the network.

The transition from an unregulated electric drive to a regulated one is one of the main ways of energy saving in an electric drive and in the technological sphere by means of an electric drive.

As a rule, the need to regulate the speed or torque of electric drives of production mechanisms is dictated by the requirements of the technological process.

However, there are a number of mechanisms for which speed changes are not required under the conditions of the technology, or other (non-electrical) ways of influencing the parameters of the technological process are used for regulation.

First of all, they include mechanisms for the supply of liquids and gases (fans, pumps, superchargers, compressors).

Their special position is explained by their mass, high power, as a rule, long-term operation.

These circumstances determine the significant share of these mechanisms in the country's energy balance. The total installed capacity of drive motors of pumps, fans, and compressors is about 20% of the capacity of all power plants, while fans alone consume about 10% of all electricity generated in the country.

The operational properties of centrifugal mechanisms are presented in the form of dependencies of the head H on the flow Q, and the power P on the flow q. In steady-state operation, the head created by the centrifugal mechanism is balanced by the head of the hydro-silt and the aerodynamic network into which it supplies liquid or gas.

The static component of the head is determined for pumps – by the geodesic difference between the levels of the consumer and the pump; for fans – by natural draught; for superchargers and compressors – by the pressure of compressed gas in the network (reservoir).

The point of intersection of the Q – H characteristics of the pump and determines the parameters $N – N_n$ and Q_n – regulation of the flow Q of the pump working with a constant speed is a latch at its output and changes the characteristics of the network, resulting in the point of intersection with the characteristic of the pump corresponds to the flow rate $Q_A* < 1$ [2].

By analogy with electrical circuits, regulating the flow rate by a gate valve is similar to regulating the current by increasing the electrical resistance of the circuit.

Obviously, this method of regulation is not effective from an energy point of view, since it is accompanied by unproductive energy losses in the regulating elements (resistor, gate valve). Losses on the gate are characterized by a shaded area on (Fig. 1.) Just as in an electrical circuit, it is more economical to regulate the energy source, rather than its consumer.

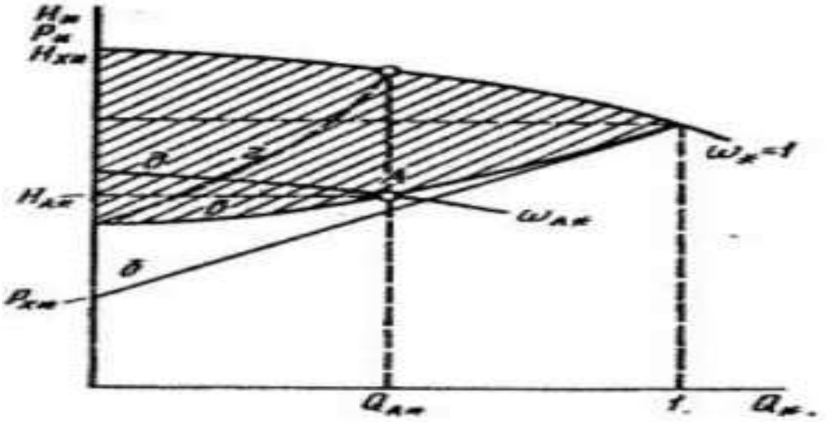

Figure 1-Q – H-characteristics of the pumping unit

In electrical circuits, the load current is reduced by reducing the source voltage. In hydraulic and aerodynamic networks, a similar effect is obtained when the pressure created by the mechanism decreases, which is realized by reducing the speed of its impeller.

When the speed changes, the operating characteristics of centrifugal mechanisms are modified in accordance with the laws of similarity, which have the form [1]:

$$Q_* = \omega_* \, , H_* = \omega_{*2} \, , P_* = \omega_{*3} \, . \quad (1)$$

The speed of the pump's impeller, at which its characteristic will pass through pointA:

$$\omega_{Д*} = \sqrt{\frac{H_{C*} + (H_{Ж*} - H_{C*})Q^2_{Д*}}{H_{Ж*}}} . \quad (2)$$

The expression for the power consumed by the pump during speed control has the form:

$$P_*[P_{Ж*} + (1 - P_{Ж*})Q_* / \omega_*]\omega_*^3 . \quad (3)$$

The quadratic dependence of the moment on the speed is typical mainly for fans, since the static component of the head, determined by natural draft, is significantly less than N_X. The technical literature sometimes uses an approximate dependence of the moment on the speed, which takes into account this property of the centrifugal mechanism:

$$M_* = w_*^n, \quad (4)$$

where n= 2 ath $_{With}$= 0 and nH$_{with}$> 0. Calculations and experiments show that n= 2-5, and its large values are typical for compressors operating on the network with a significant back pressure.

Analysis of the pump operating modes at constant and adjustable speeds shows that the excess energy consumption at ω = constis very significant. For example, the results of calculating pump operating modes with parameters $H_X* = 1.2$; $P_X* = 0.3$ per network with back pressure at different H S are shown below .$_C$.

Table 1-Analysis of pump operating modes at constant and adjustable speed

Q*	1	0,8	0,6	0,4	0,2
ω*	1	0,89	0,79	0,715	0,66
P*(ω=const)	1	0,86	0,72	0,58	0,44
P′*(ω=var)	1	0,66	0,41	0,25	0,15
$P'_{\Delta*}=P_*-P'_*$	0	0,2	0,31	0,33	0,29
$P'_{\Delta*}/P_*$	0	0,23	0,43	0,57	0,66

$H_{C*} = 0,5$

Q*	1	0,8	0,6	0,4	0,2
ω*	1	0,94	0,89	0,85	0,825
P*(ω=const)	1	0,86	0,72	0,58	0,44
P′*(ω=var)	1	0,74	0,54	0,39	0,26
$P'_{\Delta*}=P_*-P'_*$	0	0,12	0,18	0,19	0,18
$P'_{\Delta*}/P_*$	0	0,14	0,25	0,33	0,41

$H_{C*} = 0,8$

These data show that an adjustable electric drive can significantly reduce the consumption of electricity consumed: up to 66% in the first case and up to 41% in the second case. In practice, this effect can be even higher, since for various reasons (absence or malfunction of valves, manual drive), the regulation of valves is not applied at all, which leads not only to an increase in electricity consumption, but also to excess pressure and flow in the hydraulic network.

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