ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 11, Issue 4, April 2024

Opportunity to Increase Efficiency Technological Process of Cable Products

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ABSTRACT: The article presents the results of the development and implementation of energy-saving technology into production, ensuring the efficient operation of an asynchronous electric drive of a drawing machine with high energy performance based on modern semiconductor technology, taking into account the production features of the cable enterprise. It is shown that in order to improve energy performance, it is most advisable to equip the electric drive of the drawing machine with a frequency converter.

KEY WORDS: asynchronous electric drive, frequency converter, dynamic mode, electromechanical system, electric drive control system.

I. INTRODUCTION

In the context of an ever-increasing energy crisis, the rational use of energy resources and electrical energy is an urgent problem, therefore the development, research and widespread implementation of energy-saving technologies and devices is an urgent task for today and the entire subsequent period [1-5].

In the world, by improving the dynamic operating modes of technological machines and mechanisms, elements of the electromechanical system with modern control devices, improving the elements of the electromechanical system, and using control methods, energy-efficient technologies are created in various industries. At the same time, by increasing the energy efficiency of industrial installations and improving control systems for electric drives, work is being carried out to reduce electrical energy consumption and, in turn, special attention is paid to the development of this industry. As is known, the bulk of industrial, agricultural and household facilities are driven by unregulated electric drives of mass use, consuming from 60 to 70% of all electrical energy consumed by electrical installations. Of the total number of electric drives for industrial mechanisms, only a small part of the objects has a complex and finely controlled technological process for which an adjustable electric drive is used [4-6].

II. METHOD

The vast majority of these mechanisms are uncontrolled and non-automated; the installed power of the actuators, due to the provision of starting modes, is on average 1.5 - 3 times more than they actually required power.

This paper provides recommendations for improving the energy efficiency of cable production. To ensure improved energy performance, it is most advisable to equip the electric drive with a frequency converter.

As is known [1, 2], the speed of asynchronous motors is determined by two parameters: the rotation speed of the stator electromagnetic field ω0 and slip s i.e. There are two possible speed control methods: regulation by the speed of rotation of the electromagnetic field of the stator and regulation at a constant value of ω0. In turn, the rotation speed of the stator electromagnetic field is determined by two parameters: the frequency of the voltage supplied to the stator windings f_1 and the number of motor pole pairs Z_p.

Thus, two ways of speed control are possible: by changing the frequency of the supply voltage using frequency converters included in the motor stator circuit, and by changing the number of motor pole pairs.

The method of regulating the speed of an asynchronous motor by changing the number of pole pairs Z_p allows one to obtain several fixed operating speed values. For example, asynchronous motors of the 4A-6A series are available in two-, three- and four-speed types, which are used for crane electric drives. As a rule, smooth speed control is not used for such electrical machines, that is, multi-speed asynchronous motors are not used for controlled electric drive systems [1].

The frequency control method is based on converting the alternating voltage of the supply network into alternating voltage with adjustable frequency, voltage and current, which is carried out by frequency converters based on power

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semiconductor switches - thyristors and transistors. It should be noted that this method has its own advantages and disadvantages. The main advantages include the ability to carry out regulation in a wide range due to smooth regulation and high rigidity of mechanical characteristics, as well as an energy-saving operating mode due to the fact that the engine operates with small values of absolute slip.

The disadvantages are the complexity and, accordingly, high cost of frequency converters (especially for high-power drives), as well as difficulties in implementing regenerative braking for most circuits.

According to the type of connection with the supply network using semiconductor elements, frequency converters are divided into two large classes:

- frequency converters with direct coupling;
- frequency converters with DC link.

Direct Coupled Frequency Converters

The basis of the power circuit of frequency converters with direct coupling is a reversing thyristor converter. The multi-phase output of a direct coupled frequency converter is achieved by using multiple reversing converters with a single-phase output. In a direct coupled frequency converter circuit, the DC link is expressed implicitly by simultaneously combining two functions in one device - rectification and inversion. This leads to the following advantages and disadvantages of frequency converters with direct coupling.

Advantages:

- single energy conversion, which determines the high efficiency of the converter;
- the ability to pass reactive power both from the network to the load and back.

Flaws:

- complexity of control devices. A large number of thyristors requires a large number of pulse-phase control systems;
- the power factor of the converter is significantly lower than unity ($\cos\varphi \approx 0.15$);
- the shape of the supply voltage is significantly distorted;
- difficulties in obtaining frequencies close to the frequency of the supply network.

For a zero circuit, the maximum frequency of the output voltage is usually limited to $f_{1max} = 16$ *Hz.* The transition to a bridge circuit expands the operating range to $f_{1max} = 25$ *Hz*. Therefore, asynchronous electric drives with direct coupling frequency converters are used for low-speed, medium- and high-power electric drives without gearboxes.

Therefore, frequency converters with direct coupling are mainly used to power low-speed motors in medium and high power drives, which operate in dynamically intense modes, accompanied by frequent reverse, braking and recuperation [4, 8-10].

Frequency converters with a DC link, in turn, are divided into:

- for autonomous current inverters (ACI);
- autonomous voltage inverters (AVI).

In their structure, autonomous inverters contain a rectifier, a power filter and an inverter that converts direct voltage (current) into alternating voltage (current) of a given frequency.

Power semiconductor devices used in power converter devices operate only in key modes, for which there are two stable states:

- open state – maximum electrical conductivity;
- closed state – minimal electrical conductivity.

When operating in the switching mode, active power losses $P=UI$ in semiconductor devices are small, since one of the product factors (current I or voltage U) has the minimum possible value. This ensures high efficiency of electrical energy converters.

Modern frequency converters are hardware and software complexes with powerful computing and interface capabilities. A wide range of I/O expansion modules and network adapters allows you to build quite complex local automatic process control systems based on frequency converters and easily integrate them into the hierarchical structures of automated process control systems (AP CS). The operation of frequency control systems is based on automatic control of the performance of units by frequency regulation of the speed of the drive asynchronous

electric motors of these mechanisms, depending on changes in the corresponding technological parameters [6-10]. Each electric drive contains an energy-efficient power converter (the efficiency of modern inverters is not lower than 0.98) based on a transistor (IGBT) autonomous voltage inverter with pulse-width control, a built-in controller, starting and protective equipment, sensors for the corresponding operating parameters of the units. Let us note the functionality of frequency converters:

• switching on and smooth start of the electric motor;

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
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• control of frequency and output voltage, including automatic, using a real-time clock;
• automatic maintenance of the technological parameter value;
• automatic restart after emergency shutdown;
• smooth stop and shutdown of the electric motor;
• protection of the electric motor in emergency situations and abnormal conditions.

The frequency regulation system provides, along with an automatic mode, a manual control mode for mechanisms, as well as remote control using a special remote control. As a converter, it is proposed to choose a modern frequency converter with pulse width modulation (PWM). Since this type of frequency converters is the most promising due to its more stable energy performance and high-power factor. Modern frequency converters with PWM have an efficiency and a power factor of at least 0.97. In addition, frequency converters with PWM are also available without a matching transformer, which significantly improves its energy, operational and weight-size characteristics.

Frequency control systems are created for a specific technological control object or part of it. Thus, after the first stage of modernization, frequency control systems control all mechanisms with drive asynchronous electric motors at the facility and provide:

1. Maintaining a constant pressure in the water supply system.
2. Regulation of the performance of units by changing the rotation speed of their electric drive.
3. Smooth control of the electric drive rotation speed from 0 to maximum speed.
4. Ensuring soft acceleration/braking. Ability to set acceleration/deceleration time programmatically.
5. Limitation (for soft starters) and complete exclusion (for frequency converters) of starting current values.
6. Energy savings reach 50-55%.
7. Water savings reach 15-30%.
8. Providing the basic functions of protecting the electric drive of units (overcurrent; overvoltage; thermal protection of the electric motor; phase imbalance of the supply line; phase loss; short circuit protection, etc.).
9. Significant reduction in material costs for maintenance and modernization of equipment due to a significant increase in its service life.
10. Elimination of dynamic and electrical overloads when starting units.

For the electric drive of electrical equipment, the most suitable, from our point of view, is the Toshiba converter, the diagram of which is shown in Fig. 1.

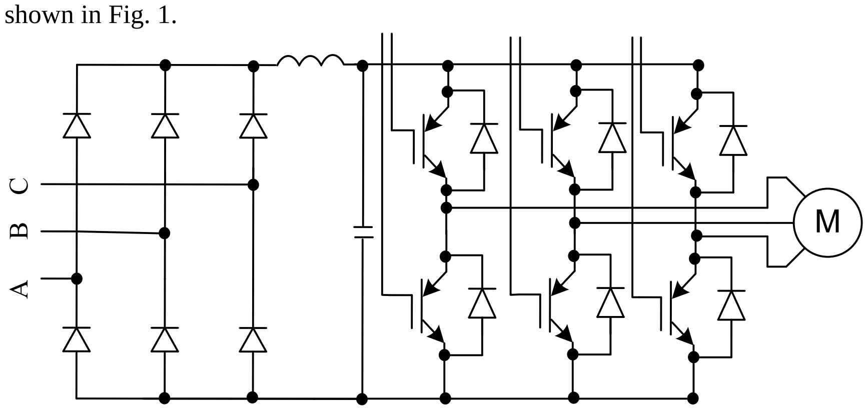

Fig. 1 - Circuit diagram of an AC frequency converter.

According to the method of controlling an electric motor, frequency converters (FCs) can be divided into two groups: with vector and scalar control, and each method has its own advantages and disadvantages [4].

Scalar control type. With scalar (frequency) control, harmonic currents of the motor phases are formed, which means that control is most often maintained at a constant ratio of the maximum motor torque to the resistance moment on the shaft. That is, when the frequency changes, the voltage amplitude changes in such a way that the ratio of the maximum motor torque to the current load torque remains unchanged. This ratio is called the overload capacity of the motor. At constant overload capacity, the rated power factor and efficiency of the engine over the entire range of rotation speed control practically do not change.

An important advantage of the scalar method is the ability to simultaneously control a group of electric motors.

The scalar control method allows for easy adjustment, even when using factory settings.

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Vector control type. Vector control is a method of controlling synchronous and asynchronous motors, which not only generates harmonic currents (voltages) of the phases, but also provides control of the rotor magnetic flux (torque on the motor shaft).

Vector control is used when during operation the load can change at the same frequency, i.e. there is no clear relationship between the load torque and the rotation speed, and also in cases where it is necessary to obtain an extended frequency control range at rated torques, for example, 0...50 Hz for a torque of 100% or even for a short time 150-200% of M_{nom}, this allows you to significantly increase control range, control accuracy, increase the speed of the electric drive. This method provides direct control of motor torque. The torque is determined by the stator current, which creates an exciting magnetic field.

With direct torque control, it is necessary to change, in addition to the amplitude and phase of the stator current, that is, the current vector. This is where the term "vector control" comes from. The vector method of controlling a frequency converter allows for much better control of the electric motor than the scalar method. But setting up such a converter requires deep knowledge in the field of electric drive design and electrical machines.

Vector control method with speed feedback - used for precision control (it is necessary to use an incremental encoder) of speed, when during operation the load can change at the same frequency, i.e. there is no clear relationship between load torque and rotation speed, and also in cases where a maximum frequency control range is required at torques close to the nominal one. The vector method works normally if the engine's nameplate values are entered correctly and its autotest has successfully passed. The vector method is implemented through complex real-time calculations performed by the converter processor based on information about the output current, frequency and voltage.

The processor also uses information about the passport characteristics of the engine, which is entered by the user. The response time of the converter to a change in the output current (load torque) is 50...200 ms. The vector method allows you to minimize the reactive current of the motor when reducing the load by adequately reducing the voltage on the motor. If the load on the motor shaft increases, the converter adequately increases the voltage on the motor. In addition, for direct torque control at low, close to zero rotation speeds, operation of a frequency-controlled electric drive without speed feedback is impossible. Vector control with a speed feedback sensor provides a control range of up to 1:1000 and higher, speed control accuracy is hundredths of a percent, torque accuracy is a few percent.

In this case, it is advisable to use vector control for the drive. Connecting the electric drive to the network "directly" leads to the fact that 6–10 times the starting currents flow through the windings, which lead to the emergence of large electrodynamic and mechanical forces, as a result of which the motor windings are subject to increased wear, the service life of the mechanical and electrical components is significantly reduced. parts of electric drive and mechanism. After reaching a steady rotation speed, the electric drive operates in underload mode, as a result of which there is an unreasonable overconsumption of the total power consumed, as a result of which the technical, economic, energy and operational indicators of the installation as a whole are reduced. At the same time, the specific energy consumption per unit of production increases.

To reduce the magnitude of starting currents of asynchronous motors and increase the energy efficiency of an automated electric drive in steady-state operating modes with a relatively low degree of load on the mechanisms, it is necessary to optimize energy parameters according to various optimality criteria (minimum stator current, maximum efficiency and power factor).

The mechanical and electromechanical characteristics of the motor were calculated and plotted using the Mathcad 2000 program. As a result of the simulation, we obtain the following characteristics of the Frequency Converter - Induction Motor (FC-IM) system (Fig. 2).

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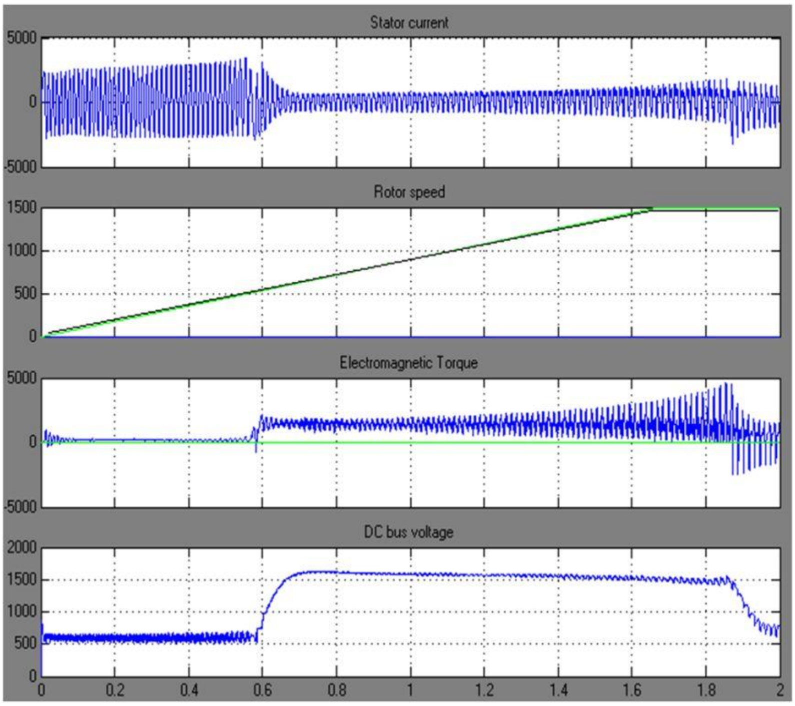

Fig. 2. Oscillograms of the IF-IM system.

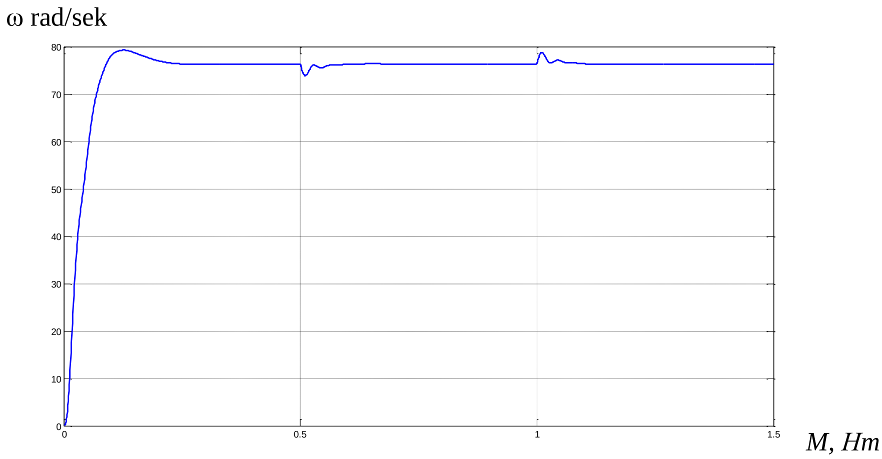

Fig. 3. Engine speed transient graph

Optimization of energy parameters for asynchronous electric drives can be realized using the “Thyristor voltage regulator-induction motor” system with microprocessor control.

The use of a thyristor voltage regulator when implementing an automated electric drive also makes it possible to increase the functionality of the system, both in static and dynamic operating modes.

The use of a microprocessor control system ensures, while maintaining the constancy of the structure of the automated electric drive, the implementation of the selected criterion for the optimality of the energy parameters of the system, ensuring a smooth start and effective protection against emergency operating conditions.

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III. CONCLUSION

Based on the foregoing, it can be stated that the development and creation of energy-saving technology that ensures the operation of asynchronous electric drives with high energy performance based on modern semiconductor technology, taking into account the production characteristics of cable enterprises, is one of the pressing problems, and the development, research and implementation of energy-saving New generation technologies that best meet modern requirements for technological drawing machines from an energy point of view are an urgent object of research.

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