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APPLICATION OF ALTERA PROGRAMMED LOGIC INTEGRATED CIRCUIT IN EFFICIENT ASYNCHRONOUS DRIVE SYSTEM

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Abstract: The work is a logical continuation of the development of an energy-efficient asynchronous drive [11], which is based on previous theoretical studies. A practical implementation based on the ALTERA programmable logic circuit (PLC) is proposed, which will contribute to the spread of energy-saving and energy-saving technologies under the condition of a deep change in the load of mechanisms of long-term operation and minimal costs for control equipment.

Key words: asynchronous drive, system of energy-efficient application, adjustable AC drive, ALTERA programmable logic integrated circuits.

1. INTRODUCTION

It is known that most electromechanical installations of mechanisms of long-term operation operate at full voltage of the power supply network without the use of regulation devices. This is accompanied by significant energy consumption, especially in unloaded modes, which may occur due to chaotic load changes. Today's conditions are such that they do not allow significant consumption of electricity due to its significant cost [1].

The best way to save energy is to use industrial frequency converters. Analysis of the cost of such equipment, especially of the world's leading manufacturers, shows its significant value, which is not always acceptable for average consumers.

The purpose of the paper is to find simple and reliable methods and to propose hardware and software solutions for the power regulation system of asynchronous drives of mechanisms of long-term operation, which will ensure greater efficiency in the use of electricity with a significant reduction in capital costs for regulatory equipment.

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2. LITERATURE REVIEW

The authors of the source [2] prove that the maximum energy efficiency of asynchronous drives of S1 operating mode mechanisms can be achieved due to a comprehensive approach in solving the set goal. Therefore, it makes sense to analyse the entire range of component of electromechanical systems of this type.

High-efficiency motors [3], despite their obvious energy advantages, are also endowed with disadvantages: significant costs in technological units; the method of frugality takes place only with a small variable load and an average moment of resistance close to the nominal one; the efficiency of the electric drive system is typical with a properly adjusted power channel.

Energy saving in network lines and power transformers involves the absence of the circulation of reactive currents that arise as a result of powering electric motors. Currently, the best compensation result is provided by the presence of RC local circuits, which additionally improve the switching modes of the control keys [4-6]. The disadvantage of systems of this type is a significant initial cost.

The use of converters with different topologies of the power part or power correctors gives a good effect of energy efficiency. At the same time, systems of this type have a significant level of capital investment [7], [8].

An evaluation of the efficiency of the frequency converter and the softstarter [9] found that their joint operation with pumping units provides a ratio of indicators of 12 to 3. It should be noted that the cost of the frequency converter exceeds the price of the parametric converter by about two times.

A system [10] that provides the desired steady-state energy efficiency can be a full-fledged substitute for the frequency converter. Its advantage is simplicity and affordable cost while simultaneously maintaining high values of power coefficients and useful system performance.

Control systems [1], [11] are a complete device for correcting the consumed power depending on the amount of load. They have desirable properties in terms of cost and technical characteristics, but the proposed system is implemented in a design form and is not adapted to conventional circuit technology. Thus, the task of the publication is to show the practical possibility of implementing the idea [1], [11] on the basis of modern FPGA schemes.

3. THE MAIN PART

The idea underlying the work is presented in the source [11]. Its essence is in the organization of the power supply of the electric machine according to the principle - at each moment of time, the amount of power that does not exceed the amount necessary to overcome the current load is supplied to the motor. At the same time, the proposed system provides two main modes: nominal, for a load close to the nominal, and efficient, for a load less than 60% of the nominal. In addition, transitional modes (start-up and transitions from mode to mode) are carried out from the intensity selector, which helps to avoid dynamic overloads, both in the mechanical and electrical parts of the electric drive. The effective mode uses the method of simultaneous reduction of voltage and frequency to the level of 0.5 nominal and at the same time maintains the sinusoidal form of the voltage, which is an important factor in the operation of the converter for an active-inductive load.

Let's consider the scheme of practical implementation of the regulation system, which is built based on the ALTERA PLC of the EMR 7032 LS-44-6 series (Fig. 1).

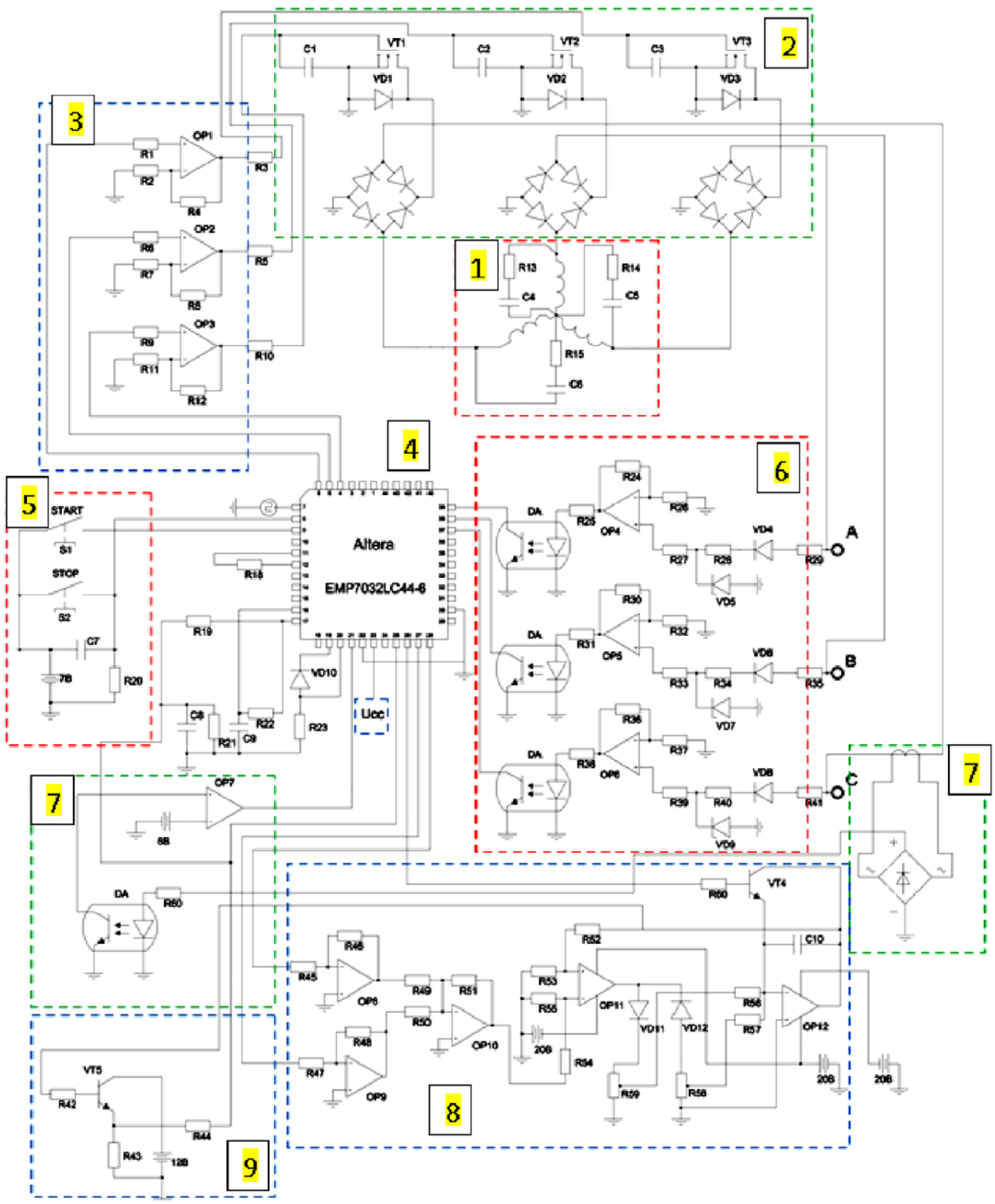


Fig. 1. Scheme of the control machine

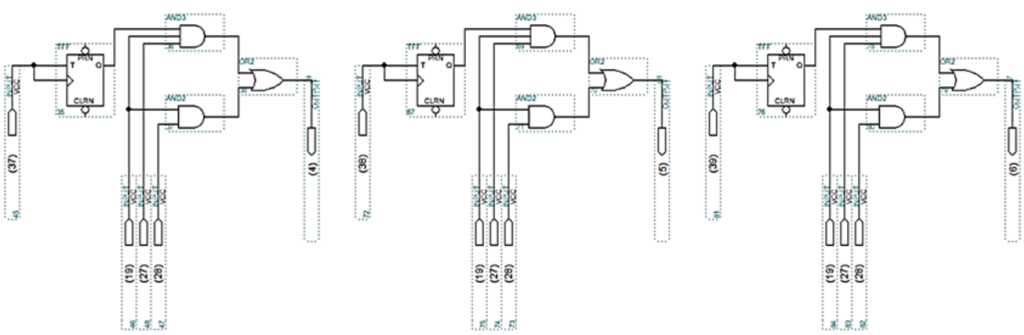
It includes a three-phase power supply marked with the letters ABC; asynchronous motor 1 with circuits of local reactive power compensation; voltage conversion link 2; power amplifiers 3; PLC 4, push-button post with forced shutdown system 5, synchronization unit of effective mode with optical solutions 6; continuous load control system 7; the voltage level matching system and the intensity setter 8 and the signal amplifier for the task of changing the spacing 9. The operation of the efficient power supply systemis ensured by an algorithm that performs the soft start function every time the start button is turned on. Control of the degree of load is carried out by continuous measurement of the phase current and its comparison with the value of the limit-determined level, after which the nominal mode is automatically switched to the effective mode and vice versa. Such transitions are limited to the corresponding time intervals, which reduces the dynamics of the system. At the same time, in the mode, the effective frequency is regulated by passing every second period of the mains voltage, and the voltage level is regulated by the PWM method. Stopping the system - pressing the stop button.

A feature of the design of the ALTERA FPGA of the EMR 7032 LS-44-6 series is the need to configure it according to a previously developed electronic circuit project, which is built on the basis of separate logical elements. The FPGA configuration program is shown in Fig. 2. It includes three independent fragments of schemes. Their development and research was carried out on the basis of the electronic laboratory Multisim. This approach was adopted in order to clearly and reliably make sure ofperformance of the designed circuit, and the final check of the FPGA project is performed in the MAX+II software shell.

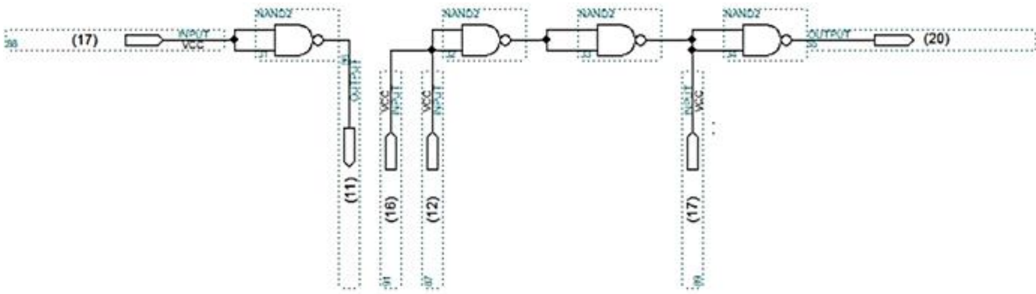
The fragment of Fig. 2, a) provides for the formation of pulses of permission to skip every second period of the mains voltage depending on the synchronization signal of Fig. 1, module 6 of the "effective" mode. In addition, this system is the performing element of switching between "nominal-effective" modes.

The auxiliary elements of the circuit in Fig. 2, b) are components of the generator of controlled splicing, which is designed to regulate the voltage level at start-up and change modes depending on the continuous control of the current sensor of the motor load.

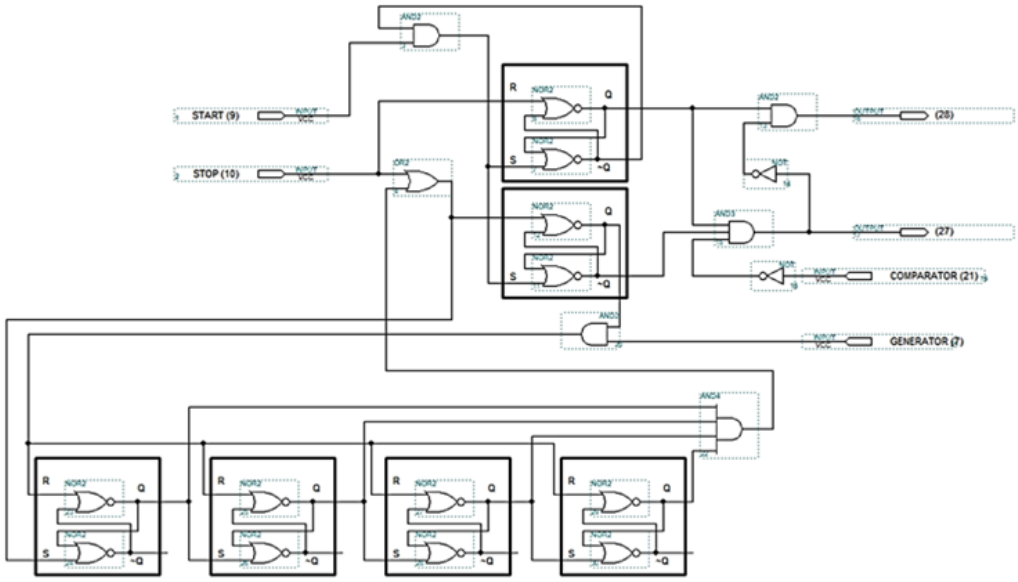
The general control system of Fig. 2, c) communicates the operator through the button post of Fig. 1, module 5 with the modules that were described above.



a)



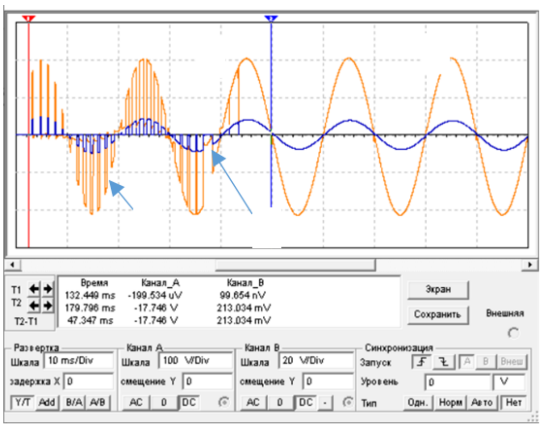
b)



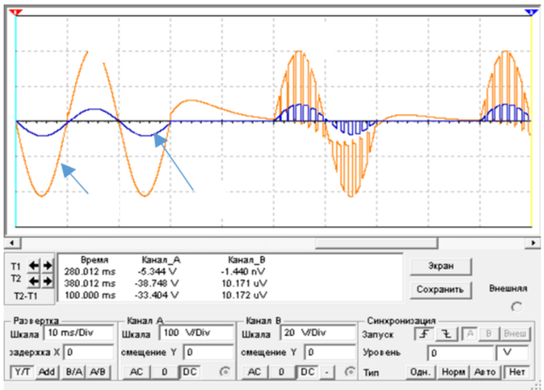
c)

a – system of modulation and mode switching; b – auxiliary circuits; c – manual control module

Fig. 2. ALTERA FPGA configuration program of the EMR 7032 LS-44-6 series

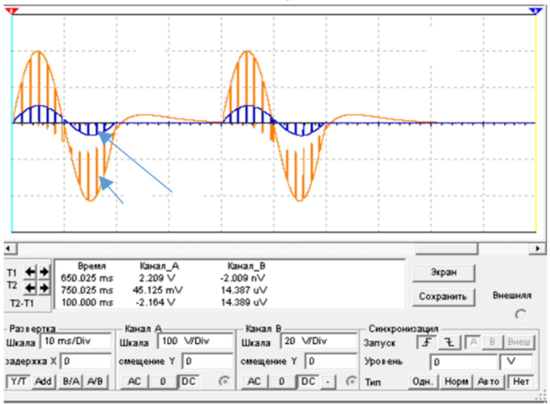


А – smooth start; Б is nominal

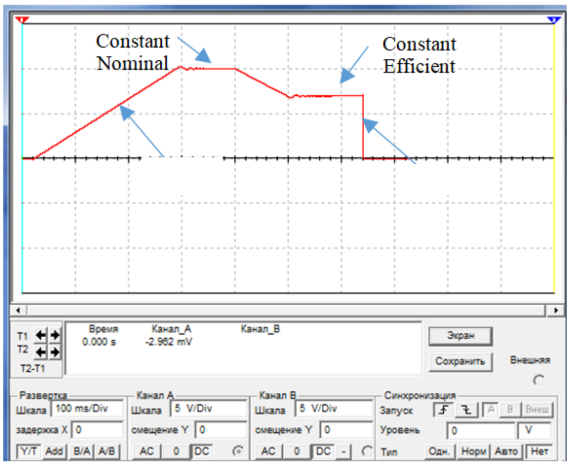


B – efficient

a)



Γ – Stop mode



Intensity selector output

b)

1 - voltage (scale 100 V/div); 2 – current (scale 20 A/division)

Fig. 3. Modeling modes [1]: a) – startup, nominal and efficient; b) –turned off.

The effective drive control system was tested on models in the Multisim environment, Fig. 3. Its ability to obtain a positive effect is confirmed by time diagrams and control of power consumption for different load levels. With a deep load change, the consumption of active power can be saved up to 40%, and reactive power can be saved up to 51%.

The scientific novelty of the work consists in proving the fundamental possibility of practical implementation of the declared control principle by means of PLSs, which will ensure rational energy consumption under the condition of the minimum cost of the control equipment.

4. CONCLUSIONS

The proposed schematic implementation of the automaton of efficient energy consumption will allow to significantly reduce losses, both for industrialists, housing, and communal services, and for any ordinary citizen, which is especially relevant during martial law.

REFERENCES

[1]. Kovaliov O., Nesterova O., Borodai V., *Automatic control of the efficiency of an asynchronous drive with a soft start function.*Microsyst Electron Acoust, vol. 26, no. 2 2021.

[2]. Kozjaruk A.E., Vasil'ev B.Ju, *Methods and means of increasing the energy efficiency of machines and technologies with asynchronous electric drives*," Bulletin of SUSU. Series "Energy", vol 15, no 1, pp. 47–53. 2015.

[3]. Bespalov V.Ja., *New high-performance series of 7AVE asynchronous motors, its modifications and specialized versions*, In Trudy VIII Mezhunar, (HIH Vseros.) nauch.-tehn. konf. po avtomatizir. elektroprivodu. pp. 239-243, 2014.

[4]. Mugalimov R.G., *Modeling of energy efficiency indicators of electric drive options of industrial plants based on the use of traditional and compensated asynchronous motors*, Bulletin of MSTU. G. I. Nosova, vol 2 (34), pp. 59-64, 2011.

[5]. Kapitonov O. A., Tret'jakov A.S., Lenevskij G.S., *Soft starter with pulse voltage regulation and compensated reactive power*. Vestnik Belorussko-Rossijskogo Universiteta, vol 4(61), pp. 39-48, 2018.

[6]. Parfenovich O. N., Kapitonov O. A., *Transistor pulse-width voltage regulator for asynchronous electric motors,* Vestnik Belorussko-Rossijskogo Universiteta, vol 3(28), pp.119-127, 2010.

[7]. Ushkov A.S., Kolganov A.R., *Energy efficiency analysis of an asynchronous electric drive with a power factor corrector,*" VestnikIGJeU, vol 6, pp.1-5, 2013.

[8]. Ushkov A.S., Kolganov A.R., *Research of modern methods of energy-saving control of asynchronous electric drive.* VestnikIGJeU, vol 2, pp.1-8, 2012.

[9]. Belousov V.Yu, Nedorezova Ye. V., *Energy saving and application of frequency converters and soft start devices.* IzvestijaTulGU. Tehnicheskienauki, vol 6, Ch. 1, pp. 148-151, 2011.

[10].. **Borodai V.A,** *Parametric control of asynchronous drive efficiency by means of the converter with the increased power factor,* Elektrotehnika ta elektroenergetyka, vol 2, pp. 8-16, 2020.

[11]. UA 151636 U Ukraine, МПК (2022) Н02К 19/36. (Utility model patent) Method of controlling an asynchronous machine / O. Nesterova, V. Borodai; applicant and patent holder of Dniprovska Polytechnic National Technical University; Application No. u 2021 06874 dated December 2, 2021; published Bull No. 34 dated 08/25/2022.

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