Diagnostics of the technical condition of energy devices based on the monitoring of phase voltages and currents.

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Abstract. *In this article, in contrast to the existing devices and methods for diagnosing the technical condition of energy devices in industrial and mining enterprises, a control and diagnostic device ZM307A has been developed, which allows regular monitoring of phase voltages of large-power synchronous motors driving the working mechanisms of electrical technological devices. Based on the application of the developed ZM307A control and diagnostic device to synchronous motors, the system for diagnosing their technical condition has been improved. As a result, accidents related to phase voltages and phase currents of synchronous motors can be detected early and prevented. The ZM307A control and diagnostic device is also relevant for solving problems related to phase voltages of large-power synchronous motors in industrial and mining enterprises.*

Basic phrases: Synchronous motor, diagnostics, device, phase voltages, phase currents, machine, mechanism, current sensor, voltage sensor, personnel, computer, monitoring, working body, operation, invalid, signal, transformer.

Enter. In the developed countries of the world, in industrial and mining enterprises, the use of synchronous machines as a motor has been widely introduced to drive large-capacity machines and mechanisms. Also, electric motors account for more than 70% of the electricity consumption produced in industries, mining, agriculture and other industries that consume large amounts of electricity. [1; 24-25-p] . Therefore, today, special attention is paid to the rational use of electricity and saving of energy resources by ensuring their efficient operation during the exploitation of electric motors, improving the control of power consumption modes of energy devices with the help of modern automated electrical systems. [2; 100-p].

Nowadays, the obsolescence of electrical technological equipment in mining enterprises and agricultural industry is significantly ahead of the rate of technical re-equipment. [3; 120-129-p]. Because during the operation stage of electric motors, the details are eroded over time due to the negative effects of the working time and the environment, the natural obsolescence parameters of the electric motor parts, network current and voltages change, therefore, during the working processes of electric motors, their electrical and mechanical There are a number of malfunctions related to the indicators, including short-circuits in the stator windings, consumption of current and voltage exceeding the standard value, etc. [4; 62-65-p].

The main part. Currently, due to accidents related to the energy-mechanical performance of electric motors in production enterprises, the annual rate of motor failure is 25%. [5; 60-67-p]. The failure of electric motors due to various accidents related to their energy-mechanical performance during the working processes leads to disruption of technological processes, reduction of product production times, increase in costs related to unplanned repairs and technological problems comes and refurbishing electric motors takes a lot of time and money [6; 64-72-b].

One of the causes of accidents that occur during the operation of synchronous motors mentioned above is the uneven distribution of phase voltages during the operation of motors and the disconnection of one of the phases. In order to prevent such problems, it is advisable to develop a device that regularly monitors the phase voltages of synchronous motors and, at the same time, enables continuous diagnostics of their technical condition. To achieve this goal, the ZM307A control and diagnostic device was developed (Fig. 1). [7; 92-93-p].

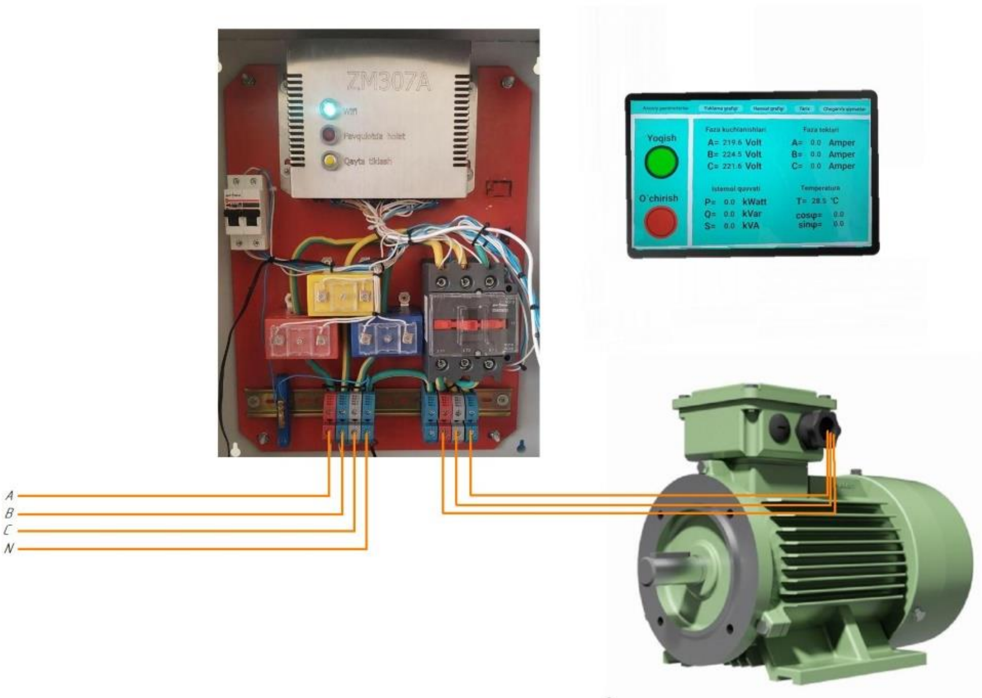

Figure 1. Overview of the ZM307A control and diagnostic device.

The main difference of the ZM307A control device from other existing devices is that it regularly monitors the state of the power device (synchronous motors) in different operating modes (salt and load), which allows to check the work efficiency of the machine. If the operating condition exceeds the specified time and any emergency occurs in the electrical technological device, it will automatically disconnect the electrical technological device from the power supply.

The ZM307A controller is assembled according to the circuit diagram created on the basis of the Proteus program (Fig. 2).

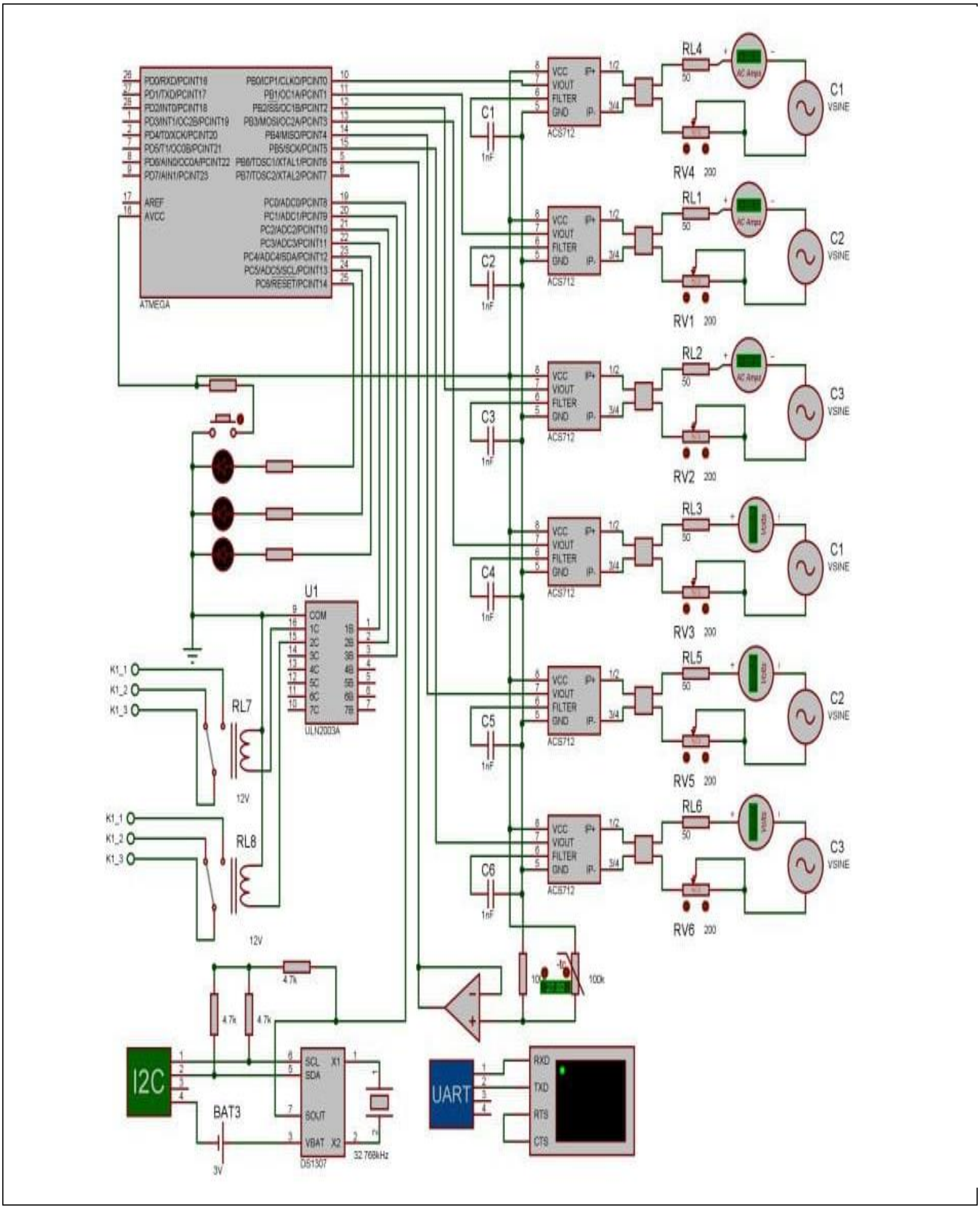

Figure 2. Circuit diagram of the ZM307A controller.

Practical and software tools are used to collect information on the working conditions of electric motors and the cost of consumed electricity. The software of the ZM307A device was created using the modern C++ programming language [12; 128-p]

Using the ZM307A control and diagnostic device, we can determine the level of distribution of phase voltages of high-power synchronous motors and whether they are present or disconnected by continuous monitoring of the motor's operating mode. The ZM307A monitoring and diagnostic device processes the data from the synchronous motor and transmits it to the personal computer in the form of a digital signal, the data from the device is displayed on the computer screen in graphic form. (Fig.3) [8; 24-25-p].

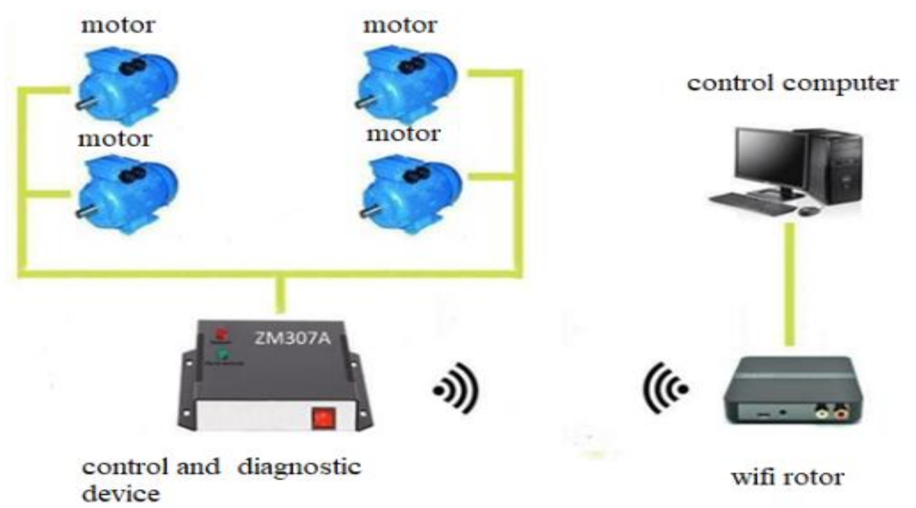

Figure 3. ZM307A control and diagnostic device control system.

We determine the phase voltages from the **synchronous motor through the voltage sensor.** An overview of the voltage sensor and the connection diagram are given below (Fig3,4) [9; 51-56-[p]. The values obtained from the voltage sensors are used to determine the phase voltage, and are transferred to the fast mode control device.

Figure 4. Overview of a voltage sensor that detects phase voltages.

The circuit diagram of the voltage sensor is shown in Figure 5. In this circuit, the common name of the voltage sensor is ZMPT101B. The electrical circuit consists of a signal amplifier, resistors of various sizes, a photodiode and capacitors.

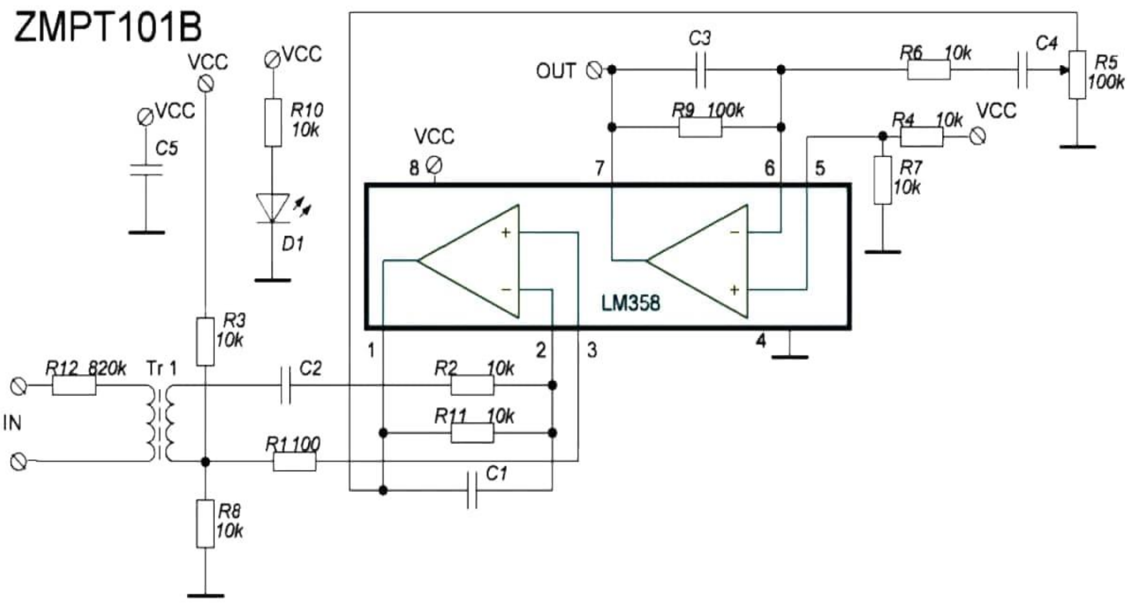

Figure 5. Phase voltage determination scheme in synchronous motors

The device processes the signal received from the voltage sensor and determines the phase voltages using the following formulas.

$$U_A = i_a \cdot \beta; \tag{1}$$

$$U_B = i_b \cdot \beta; \tag{2}$$

$$U_C = i_c \cdot \beta; \tag{3}$$

here: U_A; U_B; U_C;– phase voltages; i_a ; i_b; i_c– the signal coming from the phases; β – proportionality coefficient [10; 115-116-p]. Using the formulas (1-3), the voltages in three phases are determined and the values of the voltages are transmitted to the host computer through the ZM307A controller.

We use current transformers to determine ***the phase currents coming to the synchronous motor.*** In this case, current transformers are installed on each phase and its value is determined. An overview of the current sensor is shown below (Fig. 6).

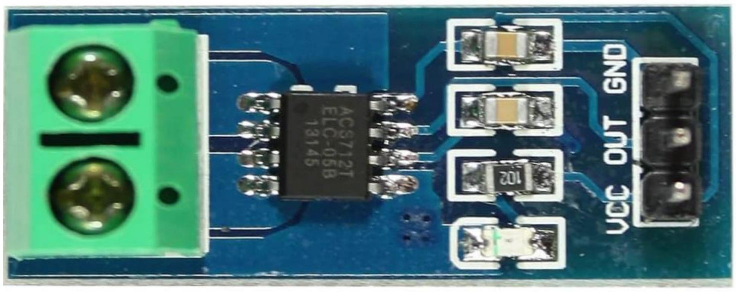

Figure 6. Current sensor overview.

Figure 6 shows an overview of the current sensor, where the UCC-signal input; OUT indicates the output of the signal. The data received from the current sensor is transmitted to the ZM307A control device according to the scheme shown in Fig. 7. Current transformers are used to determine the current strength in a phase.

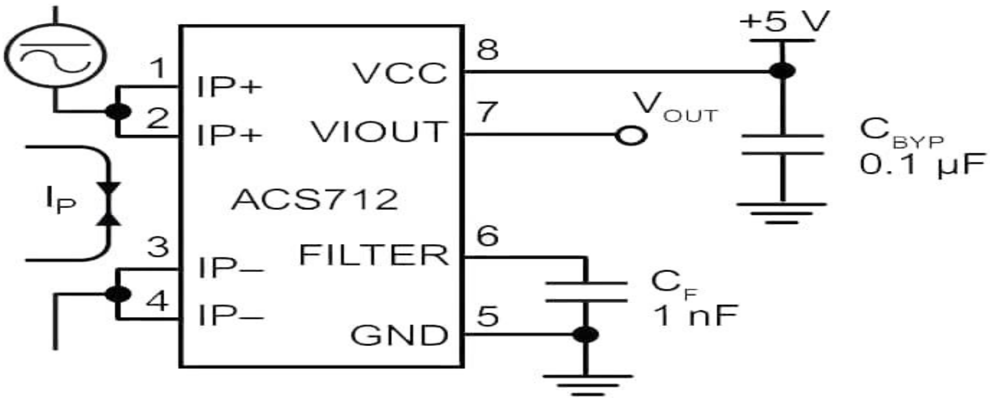

Figure 7. Phase current determination scheme of an electrical technological device

At the same time, the device processes the signal received from the current sensor and determines its current using the following formulas.

$$I_A = j_a \cdot \eta; \quad (4)$$

$$I_B = j_b \cdot \eta; \quad (5)$$

$$I_C = j_c \cdot \eta; \quad (6)$$

here: I_A; I_B; I_C – phase currents; j_f – signal from current transformer; η – coefficient of current transformer [11; 93-92-p].

The result. During the operation of electric motors, if any of the A, B, C phase voltages are disconnected, a warning signal is immediately sent to the main computer and the control device automatically disconnects the electric motor from the power network. The voltage values of the synchronous motor in normal and emergency mode are displayed graphically on the main computer screen (Fig 8,9).

We know that in the initial working process of machines and mechanisms A; B; If voltage losses from C phases are not observed, the motor works in normal mode (fig.8).

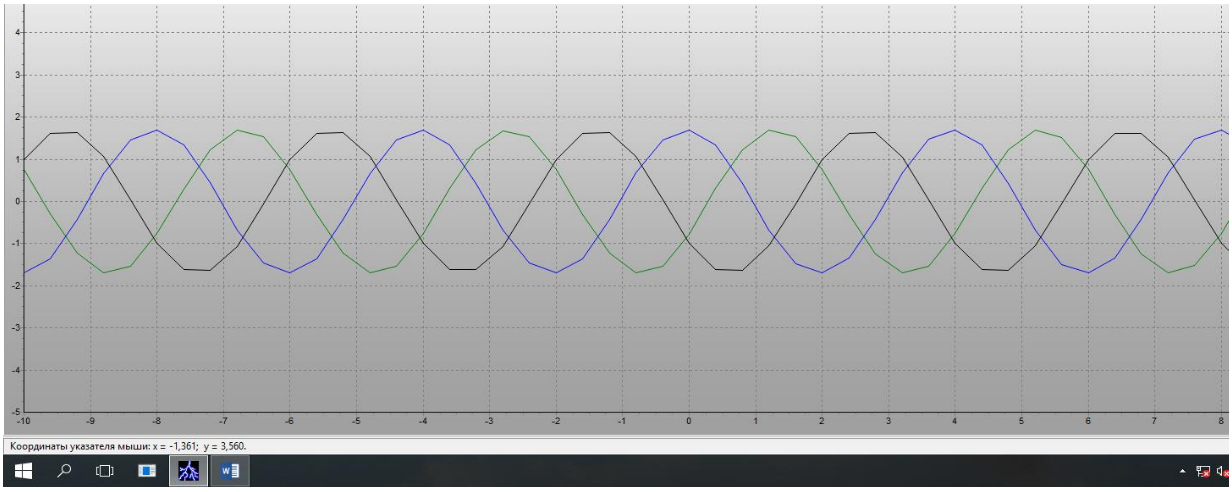

Figure 8. Phase voltages when the synchronous motor is operating in normal mode.

In Figure 8, the black line is phase A, the blue line is phase V, and the green line is phase C. In this case, the phase shift angle between the three phases and the order of movement depending on the position are the same, this process indicates the state of operation of the synchronous motor in the normal mode. If the phase voltages of the synchronous motor are in normal mode, the relationship between the phase currents is as follows (Fig.9).

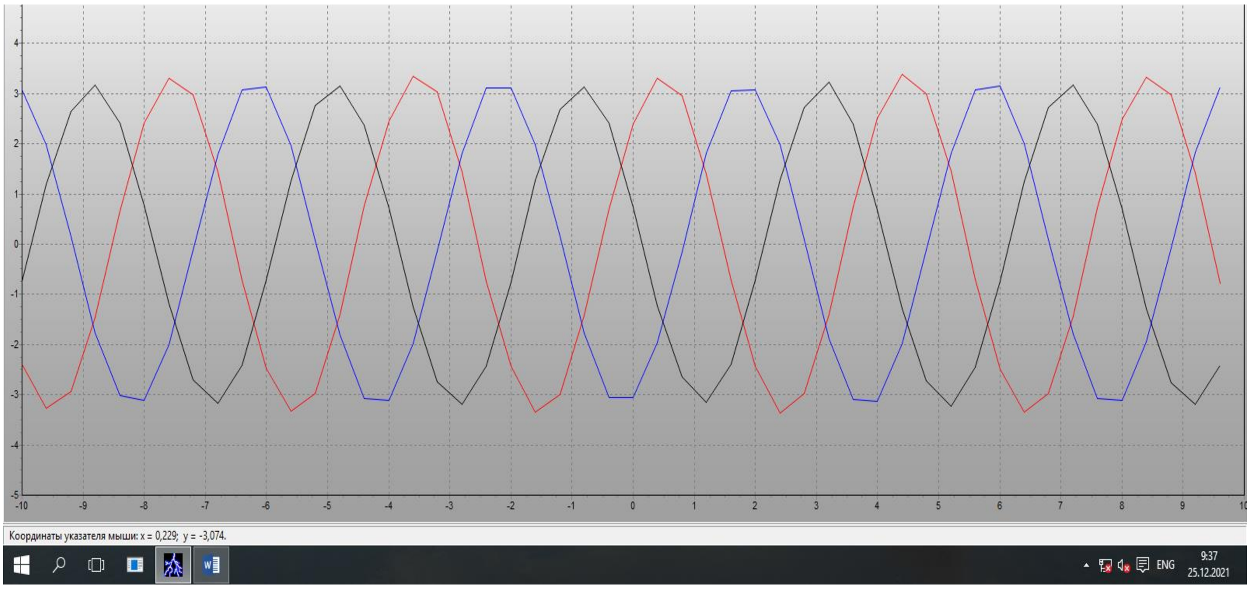

Figure 9. Graphic representation of phase currents when a synchronous motor is operating in normal mode.

Over time, one of the phase voltages may be interrupted due to power supply failures (Figure 10).

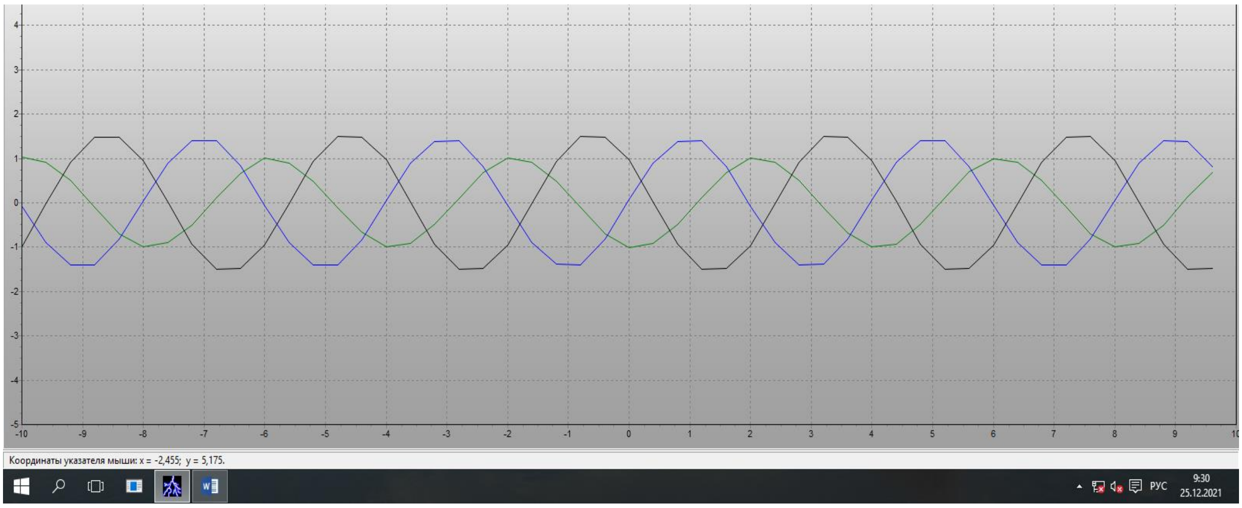

Figure 10. Graphic representation of synchronous motor phase voltages when phase C is broken.

As can be seen from Figure 10, the voltage of the phase C was interrupted while the motor was running, and at this time the relationship between the phase currents can be seen in Figure 11 below.

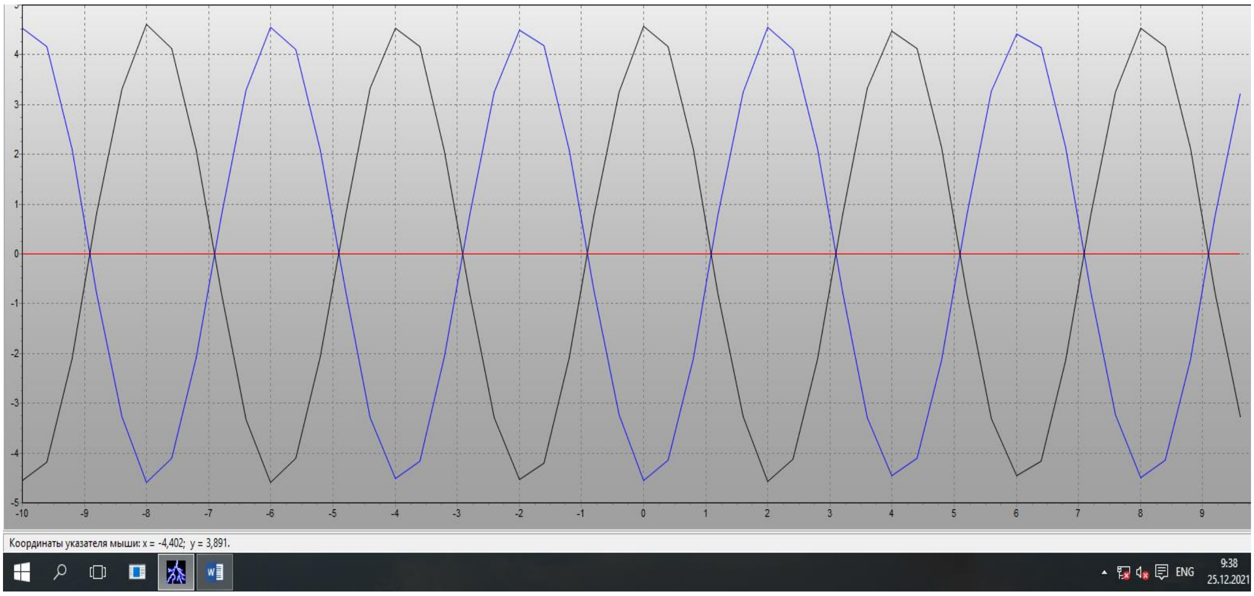

Figure 11. Graphic representation of synchronous motor phase currents when phase C is disconnected.

As can be seen from Figure 11, if one of the phase voltages is interrupted during the operation of electric motors, this situation will significantly affect the phase currents consumed by the electric motor. The electric motor works in the overload mode, as a result, the electric motor begins to consume excess electricity. This, in turn, increases the engine's heating temperature and causes the electric motor to fail. The ZM307A monitoring and diagnostic device displays their movement graphically on the main computer screen (Figures 8, 9, 10, 11) when one of the phase voltages is interrupted and also warns the operator with a sound signal, if even after the warning signal, the motor is still if not disconnected from the power supply, the device will automatically disconnect the motor from the power supply. When the engine cannot be started until the accident is eliminated, that is, the control and diagnostic device does not allow starting, because the accident is stored in its memory.

Summary. The purpose of applying the ZM307A control and diagnostic device to energy devices in industrial and mining enterprises, reducing expenses related to technological processes, preventing disruption of the technological cycle, to prevent engines from coming to repair ahead of time, increasing the reliability of motors, reducing excess electricity consumption, and saving electricity resources.

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