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Three-Phase Contactless Switching Device Development And Research

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ABSTRACT: The drawbacks of the switching processes, the three-phase non-contact beginning device created to address them, and information about the switching devices and their structure that are used to connect three-phase electric consumers to the network are all covered in this article. When using them, the reliability of the devices was calculated and the reliability indicators of the non-contact starter were compared with other analogues. If triacs or thyristors are used to create the non-contact starter's power circuit, an optocoupler and a microcontroller make up the control circuit. Compared to contact starters, a non-contact starting might offer quicker switching. Therefore, it is still necessary to employ these devices widely in networks with contemporary power supply systems and renewable energy sources.

KEYWORDS: thyristor, asynchronous motor, energy saving, loading, magnetic starter, starting current, contactor.

I.INTRODUCTION

Currently, the increase in demand for electricity also increases the demand for devices for connecting to the network, depending on the mode of operation of electricity consumers. As starting devices, magnetic starters and contactors are used for voltages below 1000 Volts.

These devices are designed for DC voltage 220, 440, 650, 750 Volts, AC voltage 220, 380, 500, 660 Volts. They allow to connect the consumer to the network up to 600÷1500 times per hour [1].

For some consumers, using these launchers can have dangerous consequences:

- a spark may appear between the contacts and cause a fire,
- noise production during setup and operation,
- contact welding as a result of heat.

There is a need for a device that can overcome the above shortcomings and disconnect in a short time. Taking into account the above, it is one of the urgent tasks to develop a device with a simple, reliable and contactless switching of three-phase electrical equipment [2].

II. MATERIALS AND METHODS

Development of non-contact starters for reliable connection and disconnection of three-phase electrical consumers to the electrical network is one of the urgent tasks. With this in mind, a new three-phase contactless switching device has been developed. The developed starter is designed to start three-phase consumers and electric motors, its structure and principle of operation are as follows.

The nominal parameters of the electrical network are 380 V, the frequency of the network is 50 Hz, and it consists of three phases. For low-power starters, triacs are used in the circuit, and for high-power ones, thyristors connected in opposite parallel are used. The proposed device is intended for small-power three-phase electric consumers and electric motors, and a circuit breaker is used in the power circuit [3].

Arduino MEGA microcontroller is used in the control circuit (Figure 1). This microcontroller is capable of receiving or outputting multiple unrelated signals. The microcontroller is also powered by a rectifier from the 220 V, 50 Hz network. It fully matches the parameters required by the microcontroller. Since the microcontroller has 54 input/output points (Pins), a wide range of actuation and control circuits can be assembled through it [4].

The "PUSK" button is pressed to connect the electric motor to the network using a contactless starting device. In this case, the input signal (5 V) comes to the Pin of the microcontroller. Through this signal, it gives output signals from its Pins based on the program written in the memory of the microcontroller. These signals cause optocouplers OP1, OP2, OP3 to work. Optocouplers perform the act of connecting the poles of the required control signal to the control circuit of the transistors. Consumer current begins to flow from the poles of the circuits. If it is required to disconnect the consumer from the network, the shutdown command is given to the microcontroller by pressing the "STOP" button. Output signals from Pins are stopped by the program. OP1, OP2, OP3 stop working because the output signals stop. In turn, the control circuits of the circuit breakers are also disconnected. This causes circuit breakers to disconnect the connected consumer from the network. Optocouplers and control buttons are connected in series through current-limiting resistors (R3, R'3, R"3) in order not to damage the elements in that circuit due to long-term storage of voltage. The purpose of connecting the resistors R4, R5 is that the microcontroller Pins are very sensitive, the resistors prevent the microcontroller from malfunctioning due to different wave signals or small signals. Signals that may be generated before the control buttons are pressed are turned off by the GROUND zero pole of the microcontroller. If one of the control buttons is pressed, the voltage is supplied to the required Pins, in which due to the high value of resistances R4, R5, the current flowing through the GROUND zero pole is several hundred times smaller than the current supplied to the Pin and does not cause any danger to the microcontroller. Below are the main parameters of the microcontroller [5-6].

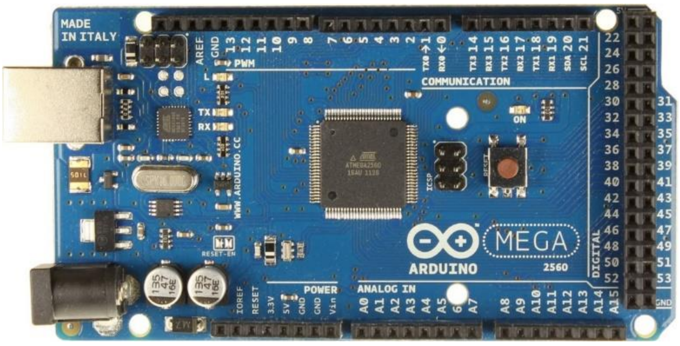

Figure 1. Microcontroller Arduino MEGA (ATmega2560)

Microcontroller parameters.

Microcontroller Arduino MEGA (ATmega2560)
Operating voltage 5 V
Supply voltage (recommended) 7-12 V
Supply voltage (limit) 6-20 V
Number of digital input/output 54 (of which 15 can be used as PWM output)
The number of analog inputs is 16
The maximum current value for the output is 40 mA
The maximum output current and voltage is 3.3 V; 50 mA
Flash memory is 256 KB, of which 8 KB is used by the bootloader
The frequency of the output current is 16 MHz.

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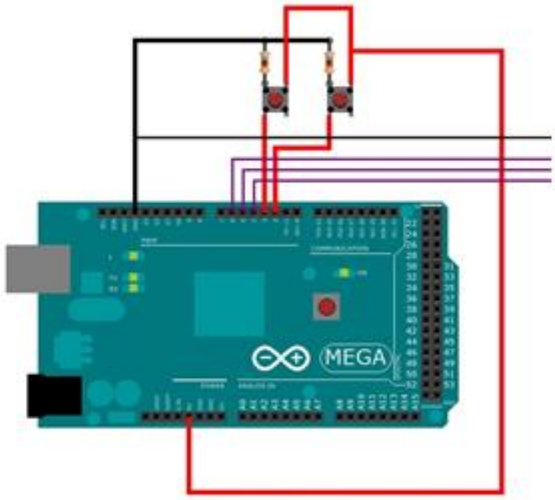

Figure 2. Connection diagram of control unit elements to Arduino MEGA (ATmega2560) microcontroller

The voltage signals to the optocouplers are given through resistors R3, R'3, R"3. The value of these resistors is selected based on the conditions for generating the required voltage and current value for the optocoupler [7-9].

III.RESULTS AND DISCUSSIONS

Reliability check.

Reliability is the ability of the device to perform its functions under specified operating conditions. Reliability is affected by: load level of circuit elements, environment, technological factors, etc.

Reliability is characterized by the average operating time $T = \frac{1}{\lambda_\Sigma}$, which in turn depends on the intensity constant λ of unexpected failures.

We check the three-phase starter for reliability.

The probability of an unexpected failure for a launcher is given by:

$$\lambda_\Sigma = \sum_{i=1}^{n} \lambda_i \qquad (1)$$

The reliability of complex equipment depends on the continuous operation of individual elements. Quantitative assessment of continuous operation requires consideration of the reliability of all elements of the device. The reliability of the device in the duration of continuous operation time t is determined mathematically from the following:

$$P = e^{-\lambda t} \qquad (2)$$

Here: λ– is the intensity constant of sudden failures;

t is the duration of continuous operation of the device.

If the device consists of n elements:

$$P_{device} = e^{-\lambda_1 t} e^{-\lambda_2 t} \dots\dots\dots e^{-\lambda_n t} = e^{-t(\lambda_1+\lambda_2+,,,,+\lambda_n)} \qquad (3)$$

In specific conditions, reliability changes unevenly over time, because operating conditions, ambient temperature have a dramatic effect on the operating mode of devices. It is possible to determine the reliability of the entire device by using information about the reliability of individual elements of the device during 1000 hours of continuous operation. λ Intensity of breakdowns for t=1000 hours when starting large-power thyristors using electromagnetically controlled small-power contacts:

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Table 1.

	Element name	λ	P
1	Capacitor	(1,4-18)· 10^{-6}	**94,19÷91,38 %**
2	Voltage relay	$50 \cdot 10^{-6}$	
3	Resistance	(3-13)· 10^{-6}	
4	Thyristor	$5{,}13 \cdot 10^{-6}$	
5	Diode	(0,3-4)· 10^{-6}	
6	Photodiode	$0{,}034 \cdot 10^{-6}$	

Thus, the reliability of the high-power thyristor starting device during 1000 hours of operation using low-power contacts controlled by Electromagnets is 94.19÷91.38%. Intensity of breakdowns of the thyristor contactless starter:

Table 2.

	Element name	λ	P
1	Diode	(0,3-4)· 10^{-6}	**94,32÷93,04 %**
2	Thyristor	$5{,}13 \cdot 10^{-6}$	
3	Resistance	(3-13)· 10^{-6}	
4	Voltage relay	$50 \cdot 10^{-6}$	
5	Soluble preservative	$0{,}011 \cdot 10^{-6}$	

The reliability of the thyristor contact starter during 1000 hours of operation is 94.32÷93.04%. Intensity of failures of circuit-free starters:

Table 3

	Element name	λ	P
1	Capacitor	(1,4-18)· 10^{-6}	**99,53÷96,92 %**
2	Optopara	0,051· 10^{-6}	
3	Resistance	(3-13)· 10^{-6}	
4	Simistor	$0{,}2 \cdot 10^{-6}$	
5	Soluble preservative	$0{,}011 \cdot 10^{-6}$	

The reliability of a simistor contactless launcher at 1000 hours of operation duration is 99.53÷96.92%.

IV.CONCLUSION

A new contactless switching device was developed to connect three-phase electric consumers to the network.

In the reliability testing of electric motors and equipment contactless launchers from renewable energy sources, the method of calculating reliability indicators, comparing values of the alternative three contactless launch schemes and elements was used. A simistor contactless launcher (P=99.53%), using small power contacts controlled by an electromagnet, was found to have better performance than a large power thyristor launcher (R=94.19%) as well as a thyristor contact launcher (P = 94.32%).

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