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RESEARCH OF OPTOELECTRONIC VOLTAGE RELAY

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Abstract: *Article represents using theoretical analysis and experimental studies of nonlinear resistive circuits and it was developed that it is important to use such circuits as power contactless switching devices to ensure a quality power supply for consumers. The paper deals with the problems of designing lightweight, reliable, high-speed contactless optoelectronic voltage relays with extended service life, combining a responsive device and a strong executive body with a sinusoidal form of the load voltage curve. Theoretical studies of transients in nonlinear dynamic circuits result in the solution of differential condition equations by a computational method built on the basis of optoelectronic pressure relays with time delay. Experimental investigations and the operating theory of this relay are addressed.*

Keywords*: optoelectronics, contactless, time delay, voltage relay, thyristor, diode bridge, capacitor, resistor.*

INTRODUCTION. Semiconductor circuits are currently typically used as power keys for devices to be switched, controlled and converted. Based on theoretical review and experimental tests of non-linear resistive circuits, it was found that circuits such as power contactless switching devices could be used to ensure a high-quality supply of power to consumers. Nonlinear resistive circuit-based schemes allow power loads to be switched under the best dynamic conditions, namely when a sinusoidal current pass through zero, ensuring an improvement in the transient process.

Often, the time delay of control pulses is important for designing circuit designs, such as relay safety and automation, parallel resistor operation, etc. The development of small, high-speed, optoelectronic contactless voltage relays with time delay is therefore critical. The creation of such relays based on resistive circuits is discussed in this article. Questions arise regarding the measurement and study of such chains when designing and developing new technologies. Non-autonomous nonlinear dynamic circuits with a diode, active resistance and capacitance are typically used at the same time. Different circuit solutions can be used in the production of control systems for automation systems [1,2].

In the control circuit of a thyristor voltage relay, various dynamic circuits can be used as a smoothing filter, connected both in series and in parallel. Figure 1, a show a circuit consisting of a diode and a parallel connected resistor and capacitance. Consider a numerical method for solving the equation of state of the circuit for this case.

METHODS. Considering that the input voltage is sinusoidal, and taking the ideal characteristic of the diode, we can conclude that the diode is open from the moment $t = 0$ to t_1, and the voltage changes across the capacitor according to a sinusoidal law, the diode is open, and the voltage changes sinusoidally across the capacitor.

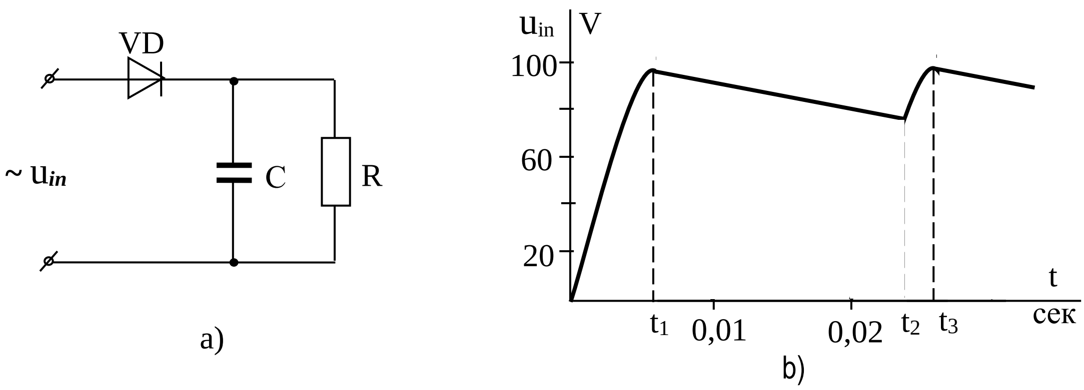


Fig. 1.a) The investigated circuit; **b)** capacitance voltage curve

The diode opens from the moment t = t_1 and the capacitor starts discharging to the resistor. It is necessary to solve the following equation of the state of the circuit to determine the law of change in the voltage across the capacitor: from the moment t = t_1, the diode opens and the capacitor starts to discharge to the resistor. It is necessary to overcome the following equation of the state of the circuit to determine the law of voltage change on the capacitor:

$$\frac{du_C}{dt} = -\frac{u_C}{RC}.$$

Let us determine the value of U_c for various points from t_1 to t_2 by setting the integration step.

$$u_{C_n} = u_{C_{n-1}} + \left(-\frac{u_{C_{n-1}}}{RC} \right) \cdot h \qquad (1)$$

For intervals $0 \le t \le t_1,\ t_2 \le t \le t_3,\ u_c = U_m Sin \omega t.$

The t_2 value is determined by the following relationship

$$\omega t_2 = \pi - arctg(\omega RC)$$

From Fig. 1. b, reveals a capacitance voltage graph obtained by solving the equation (1) on a computer for the circuit parameters C = 6,25 μF; R = 100 Ohm.

Therefore, the analysis of dynamic circuits can be successfully carried out by numerically solving the equations of state on a computer [1,2]

Let us conduct a theoretical analysis of the circuit shown in Fig. 2, where the active resistance (R1), the diode (VD) and the capacitor (C) are connected in series, and the active resistance (R2) is connected in parallel to the capacitor.

To analyze this circuit, we propose to use a numerical solution of the equation of state of the chain. [1.3]

Supply voltage variesac cording to the follo winglaw:

$$u = U_m \cdot \sin(\omega t + \varphi) \qquad (2)$$

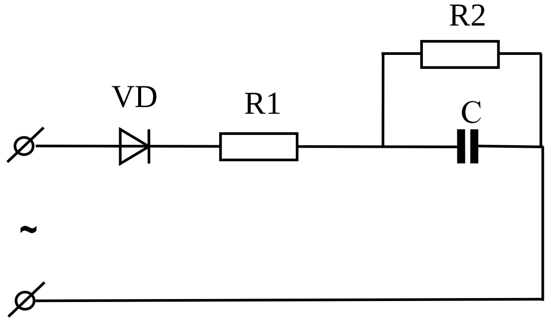


Fig. 2. Non-linear dynamic circuits with a diode, resistance and capacitance.

The voltage across the capacitance is defined by the following equation, considering the transients during periods of open state of the diode VD:

$$U_C = U_m \cdot \frac{R_2}{R_1 + R_2}\left(1 - e^{-\frac{R_1 + R_2}{R_1 \cdot R_2 \cdot C}t}\right) \quad (3)$$

Here U_m - is the rated mains voltage

Various methods of analysis of such chains are currently commonly used. We suggest that a numerical solution of the state equations of the circuit be used for this circuit by the method of Euler. In this case, an approximate solution to the equation must be calculated as follow:

$$\frac{dy}{dt} = f(t, y) \quad (4)$$

We take the characteristic of the diode as ideal and assume that $u=U_m Sin\omega t$. Then, from the moment $t=0$ to t_1, the diode is open, and the circuit equation has the following form:

$$U_m \sin \omega t = R_1\left(C\frac{dU_C}{dt} + \frac{U_C}{R_2}\right) + U_C$$

or

$$\frac{dU_C}{dt} = \frac{1}{R_1 C}\left[U_m \sin \omega t - U_C\left(1 + \frac{R_1}{R_2}\right)\right] \quad (5)$$

Where, U_C - is the voltage at the capacitance.

The solution of equation (5) according to Euler is as follows:

$$U_{C(k+1)} = U_{Ck} + f(U_{Ck}, t_k) \cdot h \quad (6)$$

Here

$$f(U_{Ck}, t_k) = \frac{1}{R_1 C}\left[U_m \sin \omega t - U_C\left(1 + \frac{R_1}{R_2}\right)\right]$$

k=0, 1, 2… h – integration step.

RESEARCH AND DISCUSSIONS. From the moment $t=0$ to $t=t_1$, the voltage across the capacitors is determined by (6) with a zero-initial condition. From the moment $t=t_1$, the diode goes into a closed state and the voltage at the capacitors is determined as:

$$C\frac{dU_C}{dt} = -\frac{U_C}{R_2} \quad (7)$$

The diode again goes into the open state from the moment t = t_3 and the voltage across the condensers is again defined by dependency (6), only with the initial conditions corresponding to the time t = t_2.

Fig 3 For different parameters of the circuit components, 3 shows the curves of the voltage over the capacitance versus time.

Fig 3 a) shows the dependencies Uc = f (t). These dependencies are constructed with a change in R_2, and R_1 and C remain constant. Curve 1 at R_2 = 3000 Ohm; 2 - R_2 = 2000 Ohm; 3 - R_2 = 1000 Ohm; 4 - R_2 = 500 Ohms; 5 - R_2 = 250 Ohm; C = 10 mF and R_1 = 300 Ohm.

Fig. 3 б) shows the dependencies Uc = f (t) plotted with a change in R_1, while R_2 and C remain constant. Curve 1 at R1 = 300 Ohms; 2 - R_1 = 500 Ohm; 3 - R_1 = 800 Ohm; 4 - R_1 = 1000 Ohm; 5 - R_1 = 1200 Ohm; C = 10 mF and R_2 = 3000 Ohm.

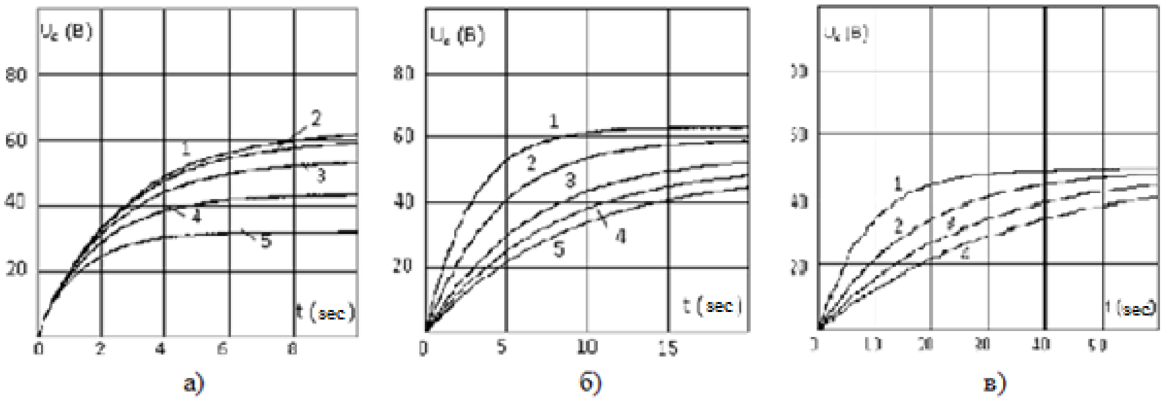


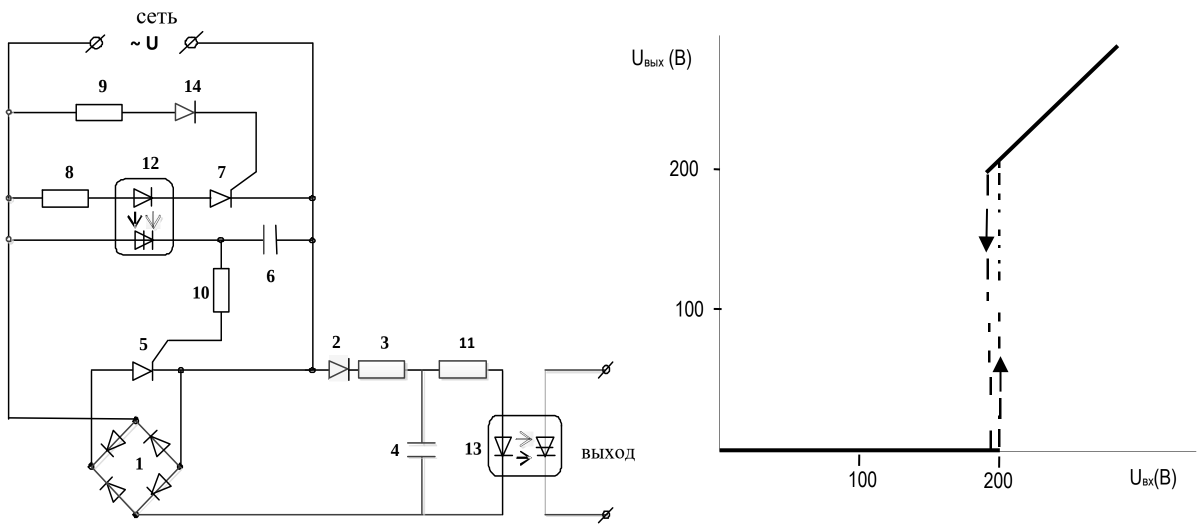
Fig. 3. Voltage versus time curves with various parameters of the circuit elements.

Fig. 3 b) shows the dependencies $U_c = f(t)$ plotted with a change in C, while R_1 and R_2 remain constant. Curve 1 at C = 10 mF; 2 - C = 20 mF; 3 - C = 30 mF; 4 - C = 40 mF; R_1 = 1200 Ohms and R_2 = 3000 Ohms.

The optoelectronic voltage relay was investigated in the laboratory of the Energy Department of Tashkent State Technical University. [4,5]

It can be seen, therefore, from Fig. 2 that a slight change in the parameter R_2 affects the charging time of the capacitor C, and a change in the parameters R_1 and C greatly changes the charging time of the capacitor and, therefore, the optocoupler's response time.

A diode bridge 1 connected to the power supply in series with diode 2, resistor 3 and capability 4 is included in the non-contact voltage relay, with the first thyristor 5 included in the relay diagonal. The relay is fitted with a capacitor 6, a thyristor 7, a thyristor optocoupler 12, 13 and a diode 14 with four resistors 8,9,10,11. The first thyristor 5 control electrode is connected to the capacitor plate 6 and the cathode of the optocoupler thyristor 12 through the first resistor 10. The second capacitor plate 6 is attached to the first thyristor 5 cathodes, the second thyristor 7 cathodes, and the first supply terminal of my mains. The anode of the second thyristor 7 is linked to the cathode of the optocoupler 12 diode, the anode of which is linked to the second resistor 8 output. The second output of resistor 8 is connected to the thyristor anode of optocoupled resistor 12 and to the first output of the third output of resistor 9, and to the second output terminal of the supply network.



a) b)

Fig. 4 shows a circuit diagram of an optoelectronic contactless voltage relay with a time delay and its experimental characteristic.

The anode of diode 14, the cathode of which is connected to the control electrode of the second thyristor 7, is connected to the second terminal of the third resistor 9. The first resistor 11 terminal is connected to the first condenser 4 plate, and the second terminal is connected to the optocoupler 13 diode anode, the cathode of which is connected to the second condenser 4 plate.
The contactless optoelectronic voltage relay with time delay works as follows. When the input voltage has reached a certain value, the unlocking signal on the control electrode will be sufficient to unlock the thyristor 7 with an opening angle of 9 and to close the optocoupler 12 diode circuit into the network through resistor 8. This contributes to the flow of current through the diode component of optocoupler 12, thus opening the thyristor component of optocoupler 12 and connecting capacitor 6 to the network. Since the direct current signal is supplied to the thyristor 5 control electrode from condenser 6 via resistor 10, it remains constantly open and the diode 11 circuit is connected to the sinusoidal voltage source by resistor 3 capacitor 4. The response time of the optocoupler thyristor 13 is controlled by selecting the resistor parameters 3 and 11, and the shutdown time by selecting the resistor parameter 11.
This non-contact voltage relay has been tested in the laboratory of the Department of Power Supply, Faculty of Energy, Tashkent State Technical University. In this case, thyristors of type KU 202 I, KU 201I were used as thyristors 5, 7, D 226 B as diodes, 2,8,9,10,11 active resistance, respectively 3 kOhm, 15 kOhm, 8 kOhm, 16 kOhm, 1.2 kOhm as a capacitance 5 - a capacitor with a capacity of 1 μF, thyristor optocoupled AOU103V, diode bridge KTs 402E were used as optocouplers. Experimental studies have shown that the relay turns on at a voltage of 200 V with a time delay of 2.3 seconds.
CONCLUSION. The following conclusions can be taken on the basis of the foregoing:
Thereby, the complex circuit analysis shown in Fig. 1 can be achieved successfully by numerically solving the state equations on a computer. The complex circuit analysis shown in Fig. 2, where the active resistor, diode and capacitance are connected in series and the active resistors are connected to the capacitance in parallel, the equations of the circuit state can be numerically solved. A qualitative study of the steady-state modes and transients of the circuits with different variations of the parameters is possible with the proposed technique (Fig.3). Using the circuit shown in Fig. 4, a non-contact, fast-acting and compact time-delayed voltage relay has been developed with its experimental characteristics, which can be adjusted by changing the active resistance parameters (3) or by changing the capacitance parameters (four).

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