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Improving the quality of 0.4 kV electricity in household appliances due to voltage regulation

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Abstract. The article discusses a way to improve the quality of electricity up to 0.4 kV household appliances through voltage regulation. As an actuator, a booster transformer with two secondary windings connected in accordance with the primary winding is used. High-speed non-contact voltage relays are used as a device that is sensitive to changes in the input voltage, as well as a device that switches the secondary windings of a booster transformer.

1 Introduction

Electricity, as a special type of product, has certain characteristics that make it possible to judge its suitability for various production processes.

The set of characteristics under which power receivers are able to perform their functions, united by the general concept of power quality, along with reliability, safety, is one of the mandatory requirements for power supply systems. The quality of electricity is characterized by a combination of properties and indicators. Ensuring the required quality of electrical energy is a problem that is solved during its generation, transmission, distribution and consumption. The main parameter and indicator of the quality of electrical energy is considered to be voltage and its quality. The task of managing the quality of electrical energy is to provide technically acceptable values of quality indicators at the terminals of electrical receivers of electrical energy. Deviation of these indicators from acceptable values leads to a disruption in the normal operation of power receivers, a reduction in their service life, the occurrence of product defects, a decrease in productivity in industry, i.e. to various damages [1-5].

Significant results have been obtained in the field of electric energy quality management, corresponding to the achieved level of means for measuring electric energy quality indicators. It was the means of measuring voltage quality indicators that made it possible to take the next step in solving the problem of improving the quality of electrical energy [3-7].

To quantify the quality of electricity, such a system of single or generalized (integral) indicators is needed so that the quality is measurable, comparable and accessible for control and management.

Power plants produce electricity of a sufficiently high quality, and the deterioration of the quality of electricity occurs in the process of its transmission and consumption as a result of the influence of electrical receivers. The characteristic properties of electricity, necessary to determine the requirements for the system of indicators of the quality of electricity, are as follows [8-10]:

- with symmetry and sinusoidality of the three-phase voltage system and voltage and frequency values equal to or close to the nominal values for electrical equipment, the requirements formulated above are almost completely satisfied. The greatest economic efficiency can be achieved with certain deviations from the specified conditions;

- an adverse effect on consumers can manifest itself both constantly, through the accumulation of irreversible changes (marriage or undersupply of products, aging of insulation, etc.), or abruptly (failures or malfunctions in the operation of automatic devices, explosions of capacitor banks, etc.). This circumstance indicates the need to limit the permissible values by lowering the quality of electricity, which determine these negative impacts;

- electromagnetic and other characteristics of electrical systems and power supply systems of consumers change over time, as a rule, according to probabilistic laws, therefore, changes in the quality of electricity are random variables.

One of the reasons for the deterioration in the quality of electricity is the so-called "dips" of voltage, which are observed when switching powerful loads: semiconductor converters, etc. Voltage dips lead not only to a deterioration in the operation of electrical receivers at such enterprises, but also to a complete stop of the entire technological process. For example, up to 0.4 kV of household appliances causes great damage [10-14].

There are a large number of works devoted to voltage regulation using transformers and autotransformers by changing the transformation ratio. However, the switching of transformer winding taps occurs due to electromechanical contacts, which reduces their speed [15-17].

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Devices that could compensate for voltage dips in the supply network must meet the following requirements: speed and sensitivity to changes in the voltage value at the input of this device [18-19].

2 Research contactless device

Such devices include booster transformers with non-contact switching of secondary windings. The executive body that switches the secondary windings of booster transformers, which meets the above requirements, is a non-contact voltage relay developed at the Department of Electrical Engineering of the Tashkent State Technical University, the diagram of which is shown in Fig.1.

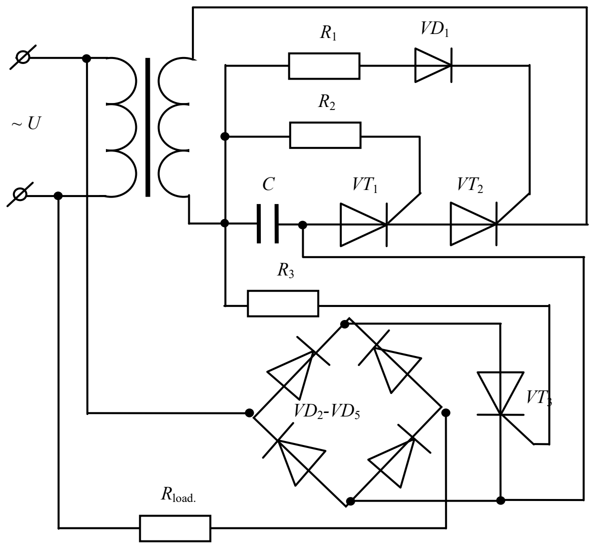

Fig.1. Schematic diagram of a non-contact thyristor voltage relay

It is known that, by controlling the thyristor triggering moment, it is possible to influence the shape of the load current curve. If the phase shift φ between the beginning of the "positive" half-cycle of the anode voltage and the beginning of the forward current flow is zero, the shape of the load current curve will be sinusoidal [20-23].

In the article, the circuit of a thyristor voltage relay with a non-sinusoidal shape of the voltage curve on the load is investigated. For many electrical installations, this is not the nominal mode of operation. To ensure the sinusoidal shape of the current and voltage curves on the load, it is necessary to achieve the opening of the thyristor when the current passes through zero [21-23].

Figure 1 shows a circuit diagram of a non-contact voltage relay with a sinusoidal voltage across the load [24-27].

Non-contact voltage relay works as follows. When a certain value of the input voltage is reached, the unlocking signal on the control electrode of the thyristor VT_2 will be sufficient to open with an angle of 90^0. After the opening of the thyristor VT_2, the thyristor VT_1 opens and the capacitor C is charged to the voltage of the secondary winding. At the same moment, from the plates of the capacitor C, a control signal pulse is applied to the power thyristor VT_3, which has the shape shown in Fig.2. Since a DC signal is applied to the control electrodes of the thyristor VT_2, it remains constantly open, and a sinusoidal current will flow through the load R_4. The moment of operation of the thyristors VT_2 is controlled by selecting the parameter of the resistor R_1 [28-30].

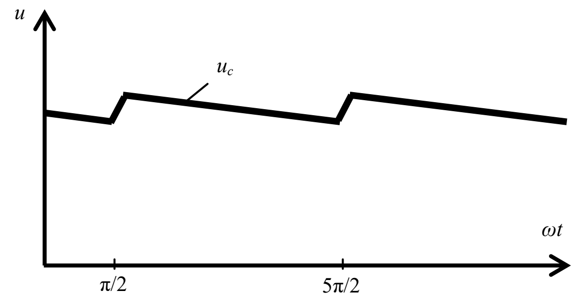

Fig. 2. The shape of the voltage curve on the capacitance

When testing, thyristors of the VT_1 - *KU202I*, VT_2 - *KU202I*, VT_3 - *KU202R* types were used as thyristors, respectively, as a *KTs402B* diode bridge, as active resistances R_1, R_2, R_3, R_4, respectively, R_1=5.6 kOhm, R_2=160 Ohm, R_3=390 Ohm, R_4=2.4 kOhm, as a capacitance C, a capacitor with a capacitance of 30 microfarads, as a transformer, a single-phase transformer with a voltage of 220/20 V was used. Experimental studies have shown that the load R_4=2.4 kOhm was connected to the network at a voltage of 200 V [31-32].

We know the contact circuit for turning on and off the windings of a booster transformer. The disadvantage of such devices is the use of a ferromagnetic element and an electromechanical key in the control unit, an increase in weight and size indicators, and a relatively low reliability of operation [25]. A non-contact device that is built according to a booster circuit has its own advantage - the switching process is carried out without interrupting the current through the load during switching of power switches [33-34].

By using non-contact voltage relays, a control system for a booster transformer was assembled, which provides the rated voltage at the load when the voltage in the supply network decreases (Fig. 3).

In Fig.3. shows a circuit diagram based on a non-contact voltage relay turning on and off the winding of a booster transformer. The device consists of two non-contact relays based on optothyristors. When a certain value of the input voltage is reached, the I-relay is activated and a control signal is given to open the power thyristor VT_4, which turns on the winding of the booster transformer to the network. With a further increase in the input voltage, the II-voltage relay is activated, shunting the diode circuit VU_1 of the optocoupler of the I-relay, with its thyristor circuit of the optocoupler. Thus, terminating the access of the control signal to the power thyristor, i.e. the switching off of the power thyristor is achieved as soon as the load current passes through zero [22, 35-37].

Consider the diagram of a non-contact switching device (Fig. 3) based on a non-contact voltage relay. The winding of the booster transformer is connected to the network by means of a diode bridge VD_3-VD_5, a controlled power thyristor VT_4 is included in the diagonal of the diode bridge. Control signals are fed to the control electrode of the power thyristor through resistor R_4 from the plates of capacitor C_1 (I-relay), which in turn is connected to the secondary winding of a low-power transformer through two low-power controlled thyristors VT_1, VT_2. The control signal for the thyristor VT_1 is supplied from the secondary winding of a low-power transformer through a series-connected R_3. The control signal for the thyristor VT_2 is supplied from the secondary winding of a low-power transformer through the series-connected R_1, R_2 and diode VD_2, as well as through the resistor R_5, since the thyristor VT_3 is closed. Disconnecting the winding of the booster transformer from the network is carried out due to the action of the second voltage relay (II), containing a limiting resistor R_4 through which a signal is supplied to the control electrode of the thyristor VT_3. The opening of the thyristor VT_3 will turn off the control signal of the thyristor VT_2 (I-relay), thereby closing VT_2 and this will turn off the control signal of the power thyristor VT_4. The rest of the relay circuit (II) is carried out in the same way as for relay (I). Variable resistors R_2 in both relays serve to adjust the pickup setting of the relay [2, 37-40].

The developed circuit of a non-contact device for switching on and off a booster transformer has an improvement in weight and size indicators and provides high reliability [31-33].

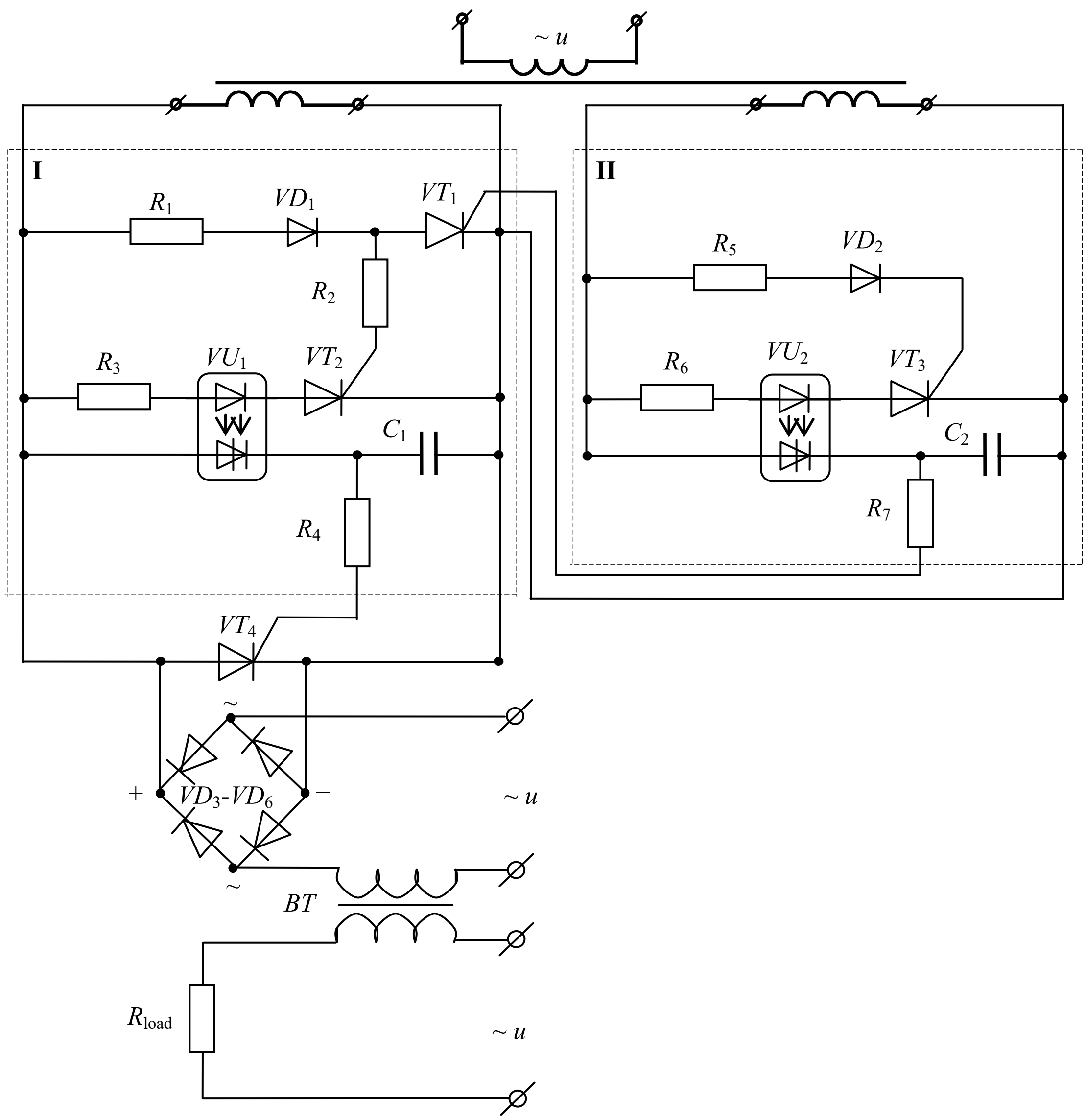

Fig. 3. Schematic diagram of a non-contact device for turning on/off the windings of a booster transformer

This non-contact thyristor device has been tested in the laboratory of the Department of Electrical Engineering. At the same time, thyristors of the following types were used as thyristors VT_1, VT_2, VT_3, VT_4: *KU202Zh*, *KU201K*, *KU202N*, *KU202E*; as diodes VD_1, VD_2 - *D226B*; R_1=820 Ohm, R_2=5,1 kOhm, R_3=1,3 kOhm, R_4=6,8 kOhm, R_5=22 kOhm, R_6=24 kOhm, R_7=6,8 kOhm, R_{load}=20 kOhm, as capacitances C_1 and C_2 - AC capacitors for 500 V. with a capacitance of 2 μF, thyristor optocouplers *MOC* are used as optocouplers

VU_1 and VU_2, diode bridge VD_3-VD_6 - *KTs402V*. Experimental studies have shown that the booster winding of transformer 3 was connected to the network at a voltage of 190 V and turned off at a voltage of 220 V [41-46].

Fig. 4 shows the input-output voltage characteristic of this device.

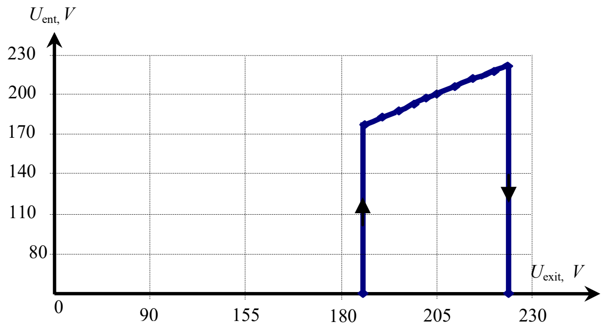

Fig. 4. Characteristic voltage “input-output”

3 Experimental analysis of non-contact voltage relay

In the research laboratory of the Department of "Electrical Engineering" of the Tashkent State Technical University, using an oscilloscope of the LeCroy WaveRunner 64 Xi-A type, experience is given and experimental data for the amplitude value of the voltage are obtained. WaveRunner 64 Xi-A Oscilloscope The 64 MXi-A was developed by LeCroy, the leading US digital oscilloscope manufacturer [47].

Fig. 5 shows the experimentally obtained oscillogram of the voltage change for an active load using a non-contact voltage relay in the control system for switching the windings of a booster transformer.

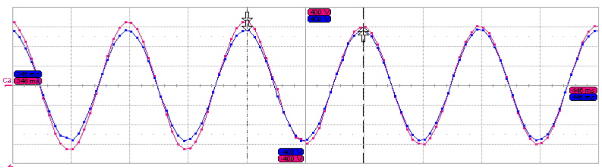

Fig. 5. Oscillogram voltage change "input-output" voltage relay

4 Conclusion

The results of the experiment show that a non-contact voltage relay in the control system will switch the windings of a booster transformer at a control voltage of 18 V in 0.32 seconds.

Thus, the purpose and objectives of the article are the results of the study: *developed non-contact voltage relay*; *With the use in the control system for switching the windings of a booster transformer, a scheme of a non-contact device is proposed*; *The application of the device has led to an energy-saving technology; reduction in energy consumption.*

Testing a prototype voltage relay to ensure the voltage deviation is within the allowable range of ±5%, which leads to an improvement in the quality of electricity.

Based on the analysis of the developed voltage relay, a scheme of a device for non-contact switching of the windings of a booster transformer is proposed in the control system.

Obtained from the control of the windings of the booster transformer, contactless switching, the energy characteristics show a high degree of reliability.

Thus, with this device, it is possible to maintain the load voltage stable.

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