Non-contact controlled voltage stabilizer for power supply of household consumers

R Karimov1*, M Bobojanov1, N Tairova1, X Xolbutayeva1, A Egamov1 and N Shamsiyeva1

1Tashkent State Technic University named after Islam Karimov, Tashkent, Uzbekistan
raxmatillo82@mail.ru

Abstract. The article discusses the principle of operation of an optoelectronic voltage relay for switching windings of a boost voltage transformer of a voltage stabilizer. Based on the simulation of the proposed optoelectronic contactless voltage stabilizer using the MATLAB R2014a program, it was determined that the change in the shape of the output voltage curve is close to a sinusoid and coincides with the results obtained by the experimental path. When modeling a voltage stabilizer, the structure of the circuit does not change, but the parameters of the resistor elements corresponding to the open or closed state of the semiconductor device at the time of switching the vents change. The characteristic of voltage changes “input-output” and the analysis of existing voltage stabilizers on the principle of “quality voltage” in rural areas

1. Introduction
In Uzbekistan, indicators of the quality of electric energy in the power supply system are characterized by eleven indicators approved by the State Standard of Uzbekistan O’zDSt 1044: 2003 and the State Standard GOST 32144-2013 [1,2,3].

The quality of electricity should be considered as two views that are interconnected: electricity as a product, the quality of which should correspond to well-defined market requirements and electricity capable of performing work in the process of its production, transmission, distribution, and consumption [3, 4, 5].

According to the requirements of a market economy, while providing consumers with high-quality electricity, legal norms and requirements apply for all participants involved from electricity production to its consumption.

Each power receiver for normal operation requires certain parameters of the network parameters, such as rated frequency, voltage, etc., that is, high-quality electric energy [5, 6, 7].

The reason for the deterioration in the quality of electricity generated by power plants may be the poor technical condition of lines and transformer substations, as well as the remoteness of consumers from the power source [7, 8, 9].

For all the above types of operating modes of the electrical system, indicators of the quality of electricity or their acceptable values and duration values are normalized separately.
2. Results and Discussion

This article discusses the main indicators of the quality of electricity - voltage deviation and in order to ensure stability, we will consider the analysis and review of the operation of stabilizing devices [1, 2, 7, 8, 9].

In power supply systems, special stabilizing devices are used as stabilizing devices to improve the quality of voltage among consumers. Common causes that lead to failure or failure of electrical equipment and process failure are power surges directly at the consumer. Any manufacturer of electrical equipment designs based on the fact that all electrical equipment and devices must be designed to operate in a network that meets the requirements of the standard [7,8,9,10].

A change in the magnitude or shape of the voltage is usually called voltage distortion. These distortions worsen the operation of electrical appliances, up to their failure. Therefore, the question arises of protecting electrical appliances from voltage changes. To avoid undesirable effects of voltage changes, as a rule, an apparatus (voltage stabilizer) is used that automatically adjusts the set voltage in the electric network [7,8,9,10,11].

In some cases, in power supply systems, the quality of electricity does not meet the requirements of O’zDSt 1044: 2003. Deviation from the nominal value, abrupt change, oscillation, high-frequency obstacle, high-voltage impulses lead to a low indicator of the quality of electricity. Applied in everyday life, household consumers are very sensitive to the quality of electricity [7]. Of these, a computer, audio equipment, a TV, a refrigerator, and a washing machine remain in danger from poor quality electric energy. In such cases, before buying household appliances, it becomes necessary to purchase voltage stabilizers. The stabilizers offered by most enterprises have their advantages and disadvantages [7,11,12,13].

Currently, the market mainly offers four groups of voltage stabilizers, which are divided according to the principles of operation: electromagnetic, electromechanical, step relay, and step electronic. Each of these groups has its positive and negative properties [8,10,14,15].

Electromagnetic voltage stabilizers. In such stabilizers, voltage stabilization occurs due to changes in the magnetic flux in the core of the transformer. In stabilizers with additional windings, a change in the magnetic flux generated by these windings leads to a change in the total flux in the core [4,8,9,16].

As control elements in these stabilizers use circuits with semiconductor elements, the speed of which characterizes the speed of the electromagnetic voltage stabilizer as a whole.

The main advantages of stabilizers of this type include smooth voltage regulation, relatively high stabilization accuracy, high speed, idling, filtering the voltage at the input and output of the stabilizer, a wide temperature range of operation, and the absence of mechanical movements.

Electromechanical voltage stabilizers with a booster transformer operate by regulating an autotransformer mounted on a servo drive shaft [3,8,12,17].

Advantages of stabilizers of this type: smooth voltage regulation, high stabilization accuracy, high overload capacity, the shape of the stabilized voltage is sinusoidal, works with zero loads, the voltage stabilizer is silent during operation, the stabilizer works well even with vibration.

The disadvantages are the presence of brush and servo wear, relatively complicated maintenance, and a heating system is required at sub-zero temperatures.

Step relay voltage stabilizers stabilize voltage by regulating the inclusion of the number of transformer windings. The number of windings is controlled by electromechanical relays [3,8,9,10].

Advantages: high stabilization accuracy, the consumption of non-ferrous metal per kilowatt of stabilized power is not large, the stabilizer operates with zero load, the phases stabilize independently, the stabilizer operates almost silently, the stabilizer is insensitive to changes in the frequency of the network, the voltage shape has an almost sinusoidal shape and a relatively wide temperature range.

Disadvantages - it has low overload capacity, relatively low speed, low reliability of the stabilizer, and the presence of wear of the mechanical parts of the relay.
Step electronic voltage stabilizers with a voltage-boost transformer stabilize voltages as well as step relay stabilizers by regulating the inclusion of the number of transformer windings. The number of windings is controlled by semiconductor circuits [8, 9, 18, 19].

The advantages include a wide temperature range of operation, there are no mechanically working contacts in the design, the consumption of non-ferrous metal per kilowatt of power is not large, the stabilizer works with zero load, is noiseless and insensitive to changes in the frequency of the network.

The disadvantages of the stabilizer include - low overload capacity, the speed of the stabilizer depends on the number of steps of the additive stage, the shape of the output voltage differs significantly from the sine wave and low reliability due to a large number of electronic keys.

One of the main indicators that determine the quality of electrical energy is the voltage stability of household consumers [2, 7, 9]. To improve the quality of the voltage of household electric consumers, voltage regulation of the boost transformer is necessary. To control the windings of the boost booster transformer, a contactless voltage relay has been developed [8, 19, 20, 21, 22].

The control circuit of the optoelectronic contactless device for turning on and off the windings of a boost-up transformer with a time delay is powered by an 18 V electric network. In this circuit, the optoelectronic optothyristors VU1, VU2 are used to electrically separate the control and the power unit. The proposed circuit works this way: when the consumer voltage reaches 220 V, the second voltage relay turns on and turns off the first relay, which turns off the winding of the boost transformer and the consumer directly connects to the network. When the voltage is reduced to 210 V, the signal from the discharge of the capacitor C2 to the control of the thyristor electrode VT3 does not receive a signal as a result of a time delay, the winding of the boost transformer is disconnected from the network. Thus, the proposed scheme of non-contact optoelectronic devices for switching windings of a boost transformer provides a rated voltage in the range of 210-220 V, that is, from the rated voltage to ±4.8% [8, 9, 10, 20, 23, 24].

A circuit of a time-delayed optoelectronic contactless device for switching windings of a boost booster transformer using the MATLAB R2014a program is simulated and the results of which are shown in Fig.1.

![Figure 1. Modeling a time-delayed optoelectronic contactless device for switching windings of a boost transformer](image)

The use of the considered equivalent circuits of semiconductor devices in modeling a voltage stabilizer leads to the fact that the structure of the stabilizers does not change, but the resistor parameters
change, which correspond to the open or closed state of the semiconductor device at the time of switching valves according to the algorithm for the corresponding type of converter [8, 9, 25, 26].

The principle of operation of the voltage stabilizer is based on switching the autotransformer windings. The proposed circuit diagram of the voltage regulator is designed for an autotransformer power of 1000 VA, which is connected via three VD7-VD10 bridges to the network (Fig.2). A VT3 thyristor is connected to the diagonal of the VD7-VD10 bridge, the control process is carried out as indicated in the previous text using a non-contact optoelectronic voltage relay with a time delay [8, 9, 21].

The control circuit is powered by an additional winding of the autotransformer with a voltage of 18 V. The stabilizer works as follows: at a nominal voltage of 220 V, and II relay is turned on and a part of the autotransformer windings is turned on, providing the consumer with a rated voltage of 220 V [9, 13, 27].

At the same time, the MOP type opto-relay opens its normal closed contact and disconnects the I-relay circuit, when the voltage drops to 210 V, the II-relay is disconnected while this opto-relay disconnects its contact and turns on the I-relay. To turn on the windings of the autotransformer, the I-relay opens the thyristor VT1 and the load voltage increases. Upon reaching a voltage of up to 230 V, the VT3 control gives an impulse to reduce the autotransformer windings, while the I-relay disconnects the II-relay circuit with its optocoupler [13, 22, 23, 25].

Thus, an autotransformer voltage stabilizer, when the voltage changes from 175 V to 235 V, provides a voltage within the permissible limits provided by the state standard of ± 5% of its nominal value.

Fig.3 and Fig.4 show the experimental shape of the voltage curves of a non-contact autotransformer voltage stabilizer at the load and the characteristic of the input-output voltage change [8, 12, 21, 26, 27].
3. Conclusions

1. The study of stabilizing device circuits showed that the voltage stabilizers offered by most enterprises have a complex structure with a large number of elements, and this leads to a limitation of their scope.

2. Analysis of the stabilization process shows that to regulate the stabilizer, it is necessary to use a system in the control circuit to open the thyristors at the moment the load current passes through zero.

3. Based on the analysis of the developed voltage relay, a voltage stabilizer circuit is proposed in the control system for non-contact switching of the boost transformer windings.

4. The voltage stabilizer developed in the laboratory provides stability of consumer voltage within the permissible limits of ±5% of the nominal value, with a change in the input voltage within 175 ÷ 241 V.

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