Experimental analysis of a prototype voltage stabilizer using an optoelectronic proximity voltage relay

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Abstract. This article discusses the issues of experimental analysis of power quality indicators when using a voltage stabilizer using an optoelectronic proximity voltage relay. Where, the booster voltage stabilizer, the magnetizing windings of which are switched using non-contact voltage relays made on the basis of semiconductor devices, as well as the duration of the transient process when switching active and active-inductive loads connected to the output of the stabilizer. In addition, the article provides information regarding the performance of the developed prototype voltage stabilizer using an optoelectronic contactless voltage relay and verification of an experimental study of the operation of installations with their use. Also presented is material on the experimental study of a prototype voltage stabilizer using an optoelectronic contactless voltage relay in various operating modes. Summarizing the results of experimental studies of a prototype voltage stabilizer using an optoelectronic contactless voltage relay, it can be stated that it fully meets the requirements for such devices and can ensure reliable operation of the power supply network of household electrical consumers.

1. Introduction

According to the requirements of the market economy, when providing consumers with high-quality electricity, there are legal norms and requirements for all participants involved from electricity production to its consumption. Each household electrical consumer for normal operation requires certain indicators of network parameters, such as: rated frequency, voltage, sinusoidal current and voltage, etc. provision of high-quality electrical energy. It should also be noted that the reliability of power supply depends on the quality of electricity, when consumers are provided with the required amount of electricity and continuity [1-3, 18].

In Uzbekistan, the indicators of the quality of electrical energy in the power supply system are characterized by eleven indicators approved by the State Standard of Uzbekistan O’zDSt 1044: 2003 [2] and the Interstate Standard GOST 32144-2013 [3, 16, 18]. This article discusses the experimental analysis of a prototype voltage stabilizer using an optoelectronic proximity voltage relay.

2. Results and discussion

In power supply systems, special technical means of regulation are used as stabilizing devices to improve the quality of voltage at consumers. Common reasons that lead to the failure or failure of electrical...
equipment and the failure of the technological process are voltage surges directly at the consumer. Any manufacturer of electrical equipment designs on the basis that all electrical equipment and devices must be designed to operate on a network that meets the requirements of the standard [4-5].

A change in the magnitude or shape of a voltage is commonly referred to as voltage distortion. These distortions impair the performance of electrical appliances, up to and including their failure. Therefore, the question arises of protecting electrical appliances from voltage changes.

To avoid undesirable influences of voltage changes, as a rule, an apparatus (voltage stabilizer) is used, which automatically regulates a given voltage in the electrical network [6-7].

The voltage stabilizer is designed for automatic regulation of the mains supply voltage of various high-power household appliances and electronic equipment. It is allowed to use stabilizers for power supply of industrial and technical equipment.

The stabilizer can be operated in a room with an ambient temperature of +10°C to +40°C, relative humidity 80% at 25°C. The operating mode is long-term, under supervision. The stabilizer is an optoelectronic contactless voltage relay of the booster windings of the transformer [8-9].

Structurally, the voltage stabilizer using a contactless device is made in the form of a metal case. On the front panel there is an LED indicator of the input voltage. On the side wall there is a terminal block for connecting input and output wires, a circuit breaker and a grounding bolt. A booster transformer, an electronic control board and a contactless relay unit are located inside the case [6-9].

The input voltage is supplied from the terminal block, through the circuit breaker, to the input windings, and is removed from the additional windings through a discrete switching circuit. The optoelectronic circuit monitors the input voltage and, if it deviates outside the set limits, issues a command to the proximity relay to switch the booster transformer windings [7-8].

Only specialists with a tolerance group of at least 3, who know safety precautions during the operation of electrical installations, are allowed to install and maintain the stabilizer. Before turning on the stabilizer, you must make sure that it is working properly, i.e. in the absence of mechanical damage and correct connection of electrical wires and the ground loop [8-9].

It is unacceptable: to connect the voltage stabilizer using a contactless device to a network with a different frequency or to a DC network; turn on the stabilizer without grounding; open or move the stabilizer while it is on; place the stabilizer next to radiators, stoves and other heating devices or cover it; repair the stabilizer at home [8-10].

When connecting the stabilizer, the correct connection of the phase and neutral wires must be ensured. As protection against short circuit and overcurrent in the stabilizer, an automatic switch is installed, which is connected to the phase wire at the input of the stabilizer [7-9].

Install the stabilizer vertically in a place designated for it, free from shocks and vibrations. Connect the stabilizer to the ground loop through the grounding bolt on its side wall. Remove the cover covering the terminal block and connect the input wires, observing the polarity of the phase and neutral wires [9, 11].

Apply mains voltage. Turn on the circuit breaker on the stabilizer and make sure it works without load by measuring the input and output voltage with a voltmeter. They must correspond to the electrical (passport) parameters. Disconnect the input voltage and connect the load wires [8-9, 11].

It is recommended to connect the stabilizer with a copper stranded wire. The selection of the wire cross-section when connecting the stabilizer is given in table 1. The indicated values are recommended for a line length of up to 10 m, if its length is much longer, then it is necessary to increase the cross-section of the wires.

### Table 1. Choice of wire cross-section.

| Type and cross-section of wires | Single-phase stabilizer power, kVA |
|--------------------------------|-----------------------------------|
| Wire type - copper             | 3 6 10 15                          |
| Wire cross section, mm²        | 2.5 4 6 10                          |

When choosing a stabilizer, it must be remembered that the range of its regulation is not infinite and
the power is limited. Determine the need to install an additional high voltage protection unit in the stabilizer and the threshold for its operation. It is recommended to set the response threshold of 150-260 V [9].

The voltage stabilizer does not guarantee a voltage of 220 V at its output, since the adjustment is made stepwise with a step of 15 V, while voltage fluctuations from 205 V to 235 V are permissible at the output, which is normal for satisfactory and trouble-free operation of household appliances and industrial equipment. In the process of automatic regulation, slight blinking of lighting lamps is permissible, which does not affect the quality of the equipment [11-12].

It is recommended to install the stabilizer in the immediate vicinity of the input panel, in a closed room, protected from moisture and chemicals. The stabilizer is included in the gap between the input automaton and the load, after the meter, a copper stranded wire or cable. Zero wire is common for input and output. An automatic switch is used to protect the stabilizer from short circuit or overcurrent [6-8].

The stabilizer is designed for long-term continuous operation, at least 15 years. This period is due to the service life of the switching optoelectronic proximity voltage relay. After this period, it is recommended to replace the contactless relay unit. In the process of operation of the voltage stabilizer using a contactless device, subject to the rules of operation and the absence of overload, it does not buzz, does not distort the shape of the input voltage, and does not introduce interference. The input voltage LED is not an accurate meter, its readings are approximate and may differ from the actual mains voltage by up to 3% [8-9, 12].

Stabilizers should be stored packed, in a heated room at a temperature from +10°C to +40°C and a relative humidity of 80% at 25°C. The room should be free of acids, alkalis and other harmful impurities that cause corrosion of metals and destroy insulation [9, 12].

The device is designed to select the optimal operating mode for household appliances and industrial equipment. Optimality of the mode is achieved by determining the best parameters of the phase voltage and choosing one phase out of three incoming ones.

Three phases and zero are fed to the input of the device through the circuit breakers. The device determines the parameters of the input voltage on each phase. If the parameters of the first phase are normal, then it is connected to the output [7, 13].

3. Experimental analysis of a prototype voltage stabilizer using an optoelectronic proximity voltage relay

Figures 1÷13 show the oscillogram of the “input-output” voltage of a non-contact voltage relay with a time delay in the control system of the voltage stabilizer for switching the booster transformer windings [7-9, 13].

The proposed voltage stabilizer was tested in the research laboratory of the Department of Power Supply, in the control circuit as thyristors (VT1, VT2, VT3) - KU202N, KU201R, KU202I, as diodes (VD1, VD2) - D226B, as an active resistance R1=1.1 kΩ, R2=5.1 kΩ, R3=1.3 kΩ, R4=6.8 kΩ, R5=22 kΩ, R5=24 kΩ, R7=6.8 kΩ, as the capacitance (C1, C2) of a 50 V capacitor with an alternating voltage of 1 μF, as a diode bridge (VD3-VD6, VD7-VD10) - KVV0808, as an optoelectron (VU1, VU2) of an optothyristor type 3052219Q, 3042025Q, and also as an optorelay VR used MOC. Here, the constituent elements of the I-relay are given, the constituent elements of the II, III-relay are similar to the I-relay. Resistance of II-relay R1=820 Ohm and for III-relay R1=500 Ohm [15-18].

In the research laboratory of the “Power supply” department of the Tashkent State Technical University, using an oscilloscope of the LeCroy WaveRunner 64 Xi-A type, experience is presented and experimental data for the amplitude value of voltage are obtained. The WaveRunner 64 Xi-A 64 MXi-A oscilloscope was developed by the leading US company LeCroy for the production of digital oscilloscope and has the following specifications, which are given in [14].

Figures 1÷3 show the experimental oscillographic data of the input voltage variation within 176-241 V and the output variation 217-224 V, where by changing the input voltage using a laboratory autotransformer, the active load voltage stabilization was obtained [19-21].

The results of the experiment show that the proposed voltage stabilizer, depending on the change in
the mains voltage, ensures the stability of the load voltage better within the permissible limits according to the state standard ±5%, approximately ±2% [22-25].

Figures 4-6 show the experimental oscillogram changes in the "input-output" characteristic of a voltage stabilizer for an active load. It is known that for household consumers the standard nominal voltage of the power supply system is 220 V and a deviation of ±5% is allowed (ultimate ±10%) [26-27].

Figure 1. Characteristics of the change in voltage "input-output" (176-217 V) voltage stabilizer for resistive load.

Figure 2. Characteristics of the change in voltage "input-output" of the voltage stabilizer at the rated voltage for the resistive load.

Figure 3. Characteristics of the change in voltage "input-output" (241-224 V) of the voltage stabilizer for a resistive load.

Figure 4. Oscillogram changing the voltage "input-output" of the voltage stabilizer for an active load: \( U_{in}=175 \) V; \( U_{out}=214 \) V.

Figure 5. Oscillogram change in voltage "input-output" of the voltage stabilizer for an active load: \( U_{in}=218 \) V; \( U_{out}=219 \) V.

Figure 6. Oscillogram change in voltage "input-output" voltage stabilizer for active load: \( U_{in}=241 \) V; \( U_{out}=224 \) V.

Figure 4 shows the oscillogram of the voltage change at \( U_{in}=175 \) V (deviation from the nominal -20.4%) and the voltage across the load \( U_{out}=214 \) V (deviation from the nominal -2.72%), the input-output voltage difference is 39 B.

Figure 5 shows the oscillogram of the change in voltage at \( U_{in}=218 \) Volt (deviation from the nominal -0.9%) and voltage across the load \( U_{out}=219 \) V (deviation from the nominal -0.45%), the voltage difference “input-output” is 1 V.

Figure 6 shows the oscillogram of the voltage change at \( U_{in}=241 \) V (deviation from the nominal 8.71%) and the voltage across the load \( U_{out}=224 \) V (deviation from the nominal 1.78%), the input-output voltage difference is 17 V.

The results of the analysis of the voltage oscillogram can be seen that, when the input voltage changes from -20.4% to +8.71%, with the help of a voltage stabilizer, the output voltage can be obtained in the range from -2.72% to +1.78%. Hence it can be seen that the developed prototype of the voltage stabilizer
provides the requirement of the state standard with voltage stability within ±5% [6, 28-30].

Figures 7÷8 show the experimentally obtained oscillogram of voltage variation for an active load using a non-contact voltage relay with a time delay in the control system for switching the booster transformer windings.

Figure 7 shows the actuation process in 0.198 seconds, a non-contact voltage relay with a time delay in the control system with an increase in the input voltage [31-33].

Figure 7. Oscillogram change in voltage "input-output" voltage stabilizer for active load.

Figure 8. Oscillogram of the change in the input-output voltage of the voltage stabilizer for an active load.

Figure 8 shows the actuation process in 0.199 seconds of a non-contact voltage relay with a time delay in the control system when the input voltage drops. The results of the analysis of the voltage stabilizer using a non-contact voltage relay in the control system with a time lag for an active load, the switching time of the booster stabilizer windings is 0.19 seconds.

Figures 9÷11 show the oscillogram of the change in the "input-output" characteristic obtained empirically, as well as the characteristic of the transient process passing on the load [32-34].

Figure 9. Oscillogram of the change in the input-output voltage of the voltage stabilizer for an active-inductive load: $U_{in}=175$ V; $U_{out}=213$ V

Figure 10. Oscillogram of the change in the input-output voltage of the voltage stabilizer for an active-inductive load: $U_{in}=218$ V; $U_{out}=219$ V

Figure 11. Oscillogram of the change in the input-output voltage of the voltage stabilizer for an active-inductive load: $U_{in}=241$ V; $U_{out}=223$ V

Figure 9 shows an oscillogram of the voltage change at $U_{in}=175$ V (deviation from the nominal -20.4%) and the voltage on the active load, $U_{out}=213$ V (deviation from the nominal -3.18%), the voltage difference “input-output” Is 38 V.

Figure 10 shows an oscillogram of the voltage change at $U_{in}=218$ V (deviation from the nominal -0.90%) and the voltage across the active load, $U_{out}=219$ V (deviation from the nominal -0.45%), the voltage difference “input-output” Is 1 V.

Figure 11 shows an oscillogram of the voltage change at $U_{in}=241$ V (deviation from the nominal 8.71%) and the voltage across the active load, $U_{out}=223$ V (deviation from the nominal 1.35%), the input-output voltage difference is 18 in.

Oscillogram analysis results, input voltage change from -20.4% to +8.71%, stabilized output voltage change from -3.18% to +1.35%. Hence it can be seen that the proposed voltage stabilizer meets all the requirements of the state standard and, with an active-inductive load, provide a voltage deviation within ±5% [34].

Figure 12 shows the oscillogram of the change in the transient process at $U_{in}=214$ V, the response time for an active-inductive load without a voltage stabilizer is shown. The oscillogram shows that,
without a voltage stabilizer, the continuation of the transient process with an active-inductive load is 0.52 seconds.

Figure 13 shows the oscillogram of the change in the transient process at $U_{in}=214$ V, the response time for an active-inductive load with a voltage stabilizer is shown. The oscillogram shows that, with a voltage stabilizer, the continuation of the transient process with an active-inductive load is 0.32 seconds.

**Figure 12.** Oscillogram of the change in the transient process with an active-inductive load without a voltage stabilizer.

**Figure 13.** Oscillogram of the change in the transient process with an active-inductive load from a voltage stabilizer.

### 4. Conclusions
Comparison of the oscillogram shows that, with the use of a voltage stabilizer, the time for the continuation of the transient process with an active-inductive load is reduced by 0.2 seconds.

On the basis of research work, the results of the experiment show that a contactless voltage relay with a time delay in the control system to switch the booster transformer windings at a control voltage of 18 V in 0.32 seconds.

Thus, the purpose and objectives of the research work received the research results: developed a contactless voltage relay with a time delay; with the use of a booster transformer in the control system for switching the windings of a booster transformer, a voltage stabilizer circuit is proposed; the use of the device has led to an energy-saving technology, a decrease in energy consumption.

Test the prototype voltage regulator to ensure that the voltage deviation is within ± 5% tolerance, resulting in improved power quality.

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