The tasks of dynamic compensation of reactive power are solved by means of flexible AC transmission systems using power electronics devices. The object of this study is a variable voltage regulator with a capacitive load. This paper considered the problem of the efficiency of phase voltage regulation on the capacitor battery to use it as a source to compensate for reactive power. The results of the study are presented, which justify the effectiveness of the technique for obtaining a dynamic source of reactive power based on the use of a thyristor voltage regulator with a capacitive load. A comparative study of two regimes of the regulator was carried out: the phase-controlled mode of closing fully controlled semiconductor gates and the phase-controlled mode for opening single-core semiconductor gates. Analytical expressions for angular characteristics of power according to the main harmonics are derived. It is shown that under the first mode the current through the capacitor is capacitive, which makes it possible to obtain a thyristor-adjustable capacitor battery for dynamic compensation of reactive power in power supply systems. It was found that under the second mode, simultaneously with the regulation of reactive power, there is a phenomenon of consumption from the active power supply network according to the main harmonics. This means that the regulation of current through an ideal capacity using ideal phase-controlled semiconductor gates is accompanied by the consumption of the active component of the current from the power supply network. The resulting component of active power in the electrical circuit without active resistances is proposed to be called "active artificial shear power". The results have been confirmed by studies on virtual models

Keywords: voltage regulator, fully controlled semiconductor gate, static reactive power compensator

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DETERMINING THE MODE CHARACTERISTICS OF VOLTAGE REGULATOR WITH CAPACITIVE LOAD

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1. Introduction

Reactive power is a component of full power that accompanies the physical processes of generating, transmitting, converting, and consuming active power in electric power systems, which causes additional technological losses in electrical networks and affects the quality of electrical energy. Reducing power and voltage losses in the elements of electrical networks, as well as increasing their throughput, is achieved by the optimization of reactive power flows during the management of the modes of operation of transmission and distribution systems of electrical energy. Ensuring the balance of reactive power in the established modes of power supply systems by using devices to compensate for reactive power achieves the appropriate voltage levels in the nodes of electrical networks [1–3]. The balance of reactive power during transition processes in power supply systems contributes to an increase in the reserve of static stability of the asynchronous load [4]. To solve these problems, dynamic compensation of reactive power is used, which means the installation of regulated sources of reactive power in power supply systems [5].

Effective dynamic compensation of reactive power is especially important for ensuring the stability of electricity systems during electromechanical transitive processes. In the technology of intelligent networks, the problem of dynamic compensation of reactive power is solved by the use of flexible alternating current power transmission systems (FACTS), in which the most modern means of power electronics are used to control electricity flows in power grids [6].

In general, studies on the problem of high-speed regulation of static sources of reactive power, designed to ensure the efficiency and stability of electrical supply systems, are relevant.

2. Literature review and problem statement

Among the devices of dynamic compensation of reactive power belonging to the FACTS family, two following should be distinguished: a static thyristor compensator (STC) and a static synchronous compensator (Statcom) [7]. Statcom is the most advanced, multifunctional, and universal FACTS device, built on the principle of inverting the constant voltage of a charged capacitor into the sinusoidal voltage of a given amplitude and phase using a certainly commuted fully controlled power semiconductor gates [8]. Statcom for low-voltage distribution networks and the concept of managing it are given in [9]. Paper [10] states that the Statcom is a complex and expensive device but makes it possible to control the flow in the electricity system of both reactive and active power.

Study [11] describes the principle of operation of the thyristor alternating voltage regulator (AVR), which makes it possible to adjust the power consumption by changing the effective value of the voltage applied to the load.

On this principle, STC is built – a FACTS device that makes it possible to quickly adjust the reactive power generated or absorbed by it at the point of connection [12]. At the heart of the STC is an unregulated capacitor battery and a thyristor-adjustable reactor (TAR), built using phase control of the conductive state of single-operation thyristors according to the AVR scheme with inductive load. TAR as part of STC consumes reactive power generated by an uncontrolled capacitor battery, that is, indirectly provides the possibility of dynamic compensation of reactive power in the electrical network. Thyristor phase adjustment of alternating voltage at capacitive load, which would make it possible directly to regulate the generation of reactive power by a capacitor battery, is not used in STC.

With the active nature of the load, AVRs are able to regulate the consumption of active electricity. As shown in [13], this is especially true for the creation of virtual power plants, when the consumer takes an active part in solving the issues of improving the efficiency and reliability of the functioning of electricity supply systems.

Paper [14] reports a study of the phase technique of controlling AVR thyristors with active load. It is shown that the regulation of the consumption of active power is accompanied by simultaneous adjustment of reactive power. The use of two-operation thyristors in AVR with an active load makes it possible to get a certain reactive power resource of both signs.

Study [15] describes the use of thyristor adjustment of the capacitor for longitudinal compensation of power line parameters. With the help of phase adjustment of thyristors, it is possible to change the equivalent resistance of the capacitor, which compensates for the inductive resistance of the line.

In [16], the harmonic composition of the current in the active-capacitive line is investigated using counter-parallel enabled thyristors.

From the above review, the following conclusions can be drawn. First, the only known classified compensatory means that combines the terms "thyristor condenser adjustment" is a thyristor-controlled series capacitor (TCSC), which is not directly a means of compensating reactive power. Second, a thyristor-switched capacitor battery (TSCB) is used, and a thyristor-regulated shunt capacitor battery (TRCB) is not at all in the international classification of means for reactive power compensation. In general, the possibilities of direct regulation of the power generated by the capacitor battery, with the help of thyristor AVR, are not sufficiently investigated. Therefore, it is advisable to determine the optimal variants of phase thyristor voltage regulation on capacitance, having received and compared the main energy characteristics.

3. The aim and objectives of the study

The purpose of this study is to establish the features of thyristor regulation of the capacitor battery, implemented according to the AVR scheme with capacitive load using various techniques of phase control of thyristors. This will make it possible to justify the choice of the optimal mode of adjusting the capacitor battery to obtain a resource for dynamic compensation of reactive power.

To accomplish the aim, the following tasks have been set:

– to analyze electromagnetic processes and obtain the main energy characteristics of the voltage regulator with fully controlled (two-operation) thyristors and capacitive load;

– to analyze electromagnetic processes and obtain the main energy characteristics of the voltage regulator with semi-controlled (single-operation) thyristors and capacitive load.

4. The study materials and methods

The object of this study is AVR with phase control of semiconductor gates, which feeds the capacitive load. The main hypothesis of the study is to clarify the possibility of using AVR with a capacitive load as an adjustable source of reactive power for electrical networks of power supply systems. The research was carried out by mathematical modeling of steady modes for a given technique of phase control of semiconductor gates. Two opposite techniques of phase control are adopted for the basic methods of phase control, which are proposed for virtual sources of reactive power, built according to the scheme of thyristor AVR with active load [13] since this expands the possibilities of regulating electrical power:

1. For mode 1, a technique of adjusting the duration of the conductive state of two-operational thyristors by specifying the moments of their closing time (forced rigid switching) is adopted, and the opening is provided without delay at the time of the appearance of positive anode voltage (natural soft switching).

2. For mode 2, it is accepted to adjust the duration of the conductive state of single-operation thyristors by specifying the moments of their opening time (forced switching with a delay), and closing is provided at moments of time of decline of current to zero value (natural soft switching).

In order to identify and explain the phenomena associated with the influence of phase control of thyristor AVR on energy transformations, the assumption of the sinusoidal shape of a supply voltage is accepted. In addition, losses in all elements of the scheme are neglected, and thyristors are represented as ideal semiconductor keys, switching instantly.

Verification of the obtained analytical expressions for calculating the main energy characteristics of the regulator is implemented by modeling modes in the SimPowerSystem application package of the Simulink visual programming environment of the MATLAB software package (USA).

5. Results of studying the steady modes of operation of the voltage regulator with capacitive load

5. 1. Results of modeling a phase control mode of two-operator thyristors of voltage regulator with capacitive load

Fig. 1 shows an equivalent scheme of one phase of the AVR with capacitive load and two-operator thyristors, which is accepted for the mathematical modeling of mode 1.

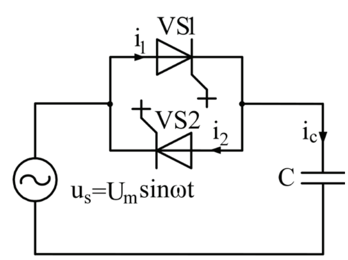

Fig. 1. Equivalent voltage regulator phase diagram with two-operator thyristors and capacitive load

Fig. 2 shows time diagrams of voltages and currents of AVR with capacitive load in the control mode of two-operator thyristors by specifying the angles of their closing. At the time corresponding to the closing angle β, which is counted from the moment of passage of the power voltage through the zero value, the *VS*1 thyristor is closed by the control pulse (Fig. 2, *c*). At the time of stopping the current on the capacitor, an unchanging voltage u_c is fixed, up to the time corresponding to the angle α_{on} of opening the antiparallel-on thyristor *VS*2 (Fig. 2, *d*), when $u_c(\alpha_{on})=u_s(\alpha_{on})$, and a positive anode voltage is applied to the thyristor. If at this point in time to submit a pulse to the control electrode of the thyristor for opening (Fig. 2, *c*), then it opens without delay.

The range of possible closing angles is $0\leq\beta\leq\pi/2$. If the closing angle $\beta=0$, then the thyristors are closed and there is no current in the capacitor. In the case $\beta=\pi/2$, thyristors switch at natural moments to close them $\omega t_{off}=\pi/2$ and open $\omega t_{on}=-\pi/2$, and the duration of the conducting state of each of the thyristors is half the period of the main frequency.

For the interval of the conducting state of the thyristor *VS*1 $\alpha_{on}\leq\omega t\leq\beta$ (Fig. 2) the following equations hold

$$\begin{cases} u_c = u_s = U_m \sin\omega t, \\ i_c = C\dfrac{du_c}{dt} = \omega C U_m \cos\omega t. \end{cases} \tag{1}$$

The value of the angle of the natural opening of the thyristor *VS*1 is obtained from the condition

$$u_c(\beta) = -u_c(\alpha_{on}), \tag{2}$$

hence $\alpha_{on}=-\beta$.

In order to obtain expressions for energy characteristics, decompose the i_c current into a Fourier series. As a result, we get the following expressions for the coefficients of the series:

$$a_n = \frac{2}{\pi}\int_{\alpha_{on}}^{\beta} i_c(\omega t)\cos n\omega t\, d(\omega t) = \frac{2}{\pi}\omega C U_m \int_{\alpha_{on}}^{\beta} \cos\omega t \cos n\omega t\, \mathrm{d}(\omega t) = \frac{1}{\pi}\omega C U_m \left\{ \frac{\sin\left[(1-n)\beta\right]}{1-n} + \frac{\sin\left[(1+n)\beta\right]}{1+n} \right\}, \tag{3}$$

$$b_n = \frac{2}{\pi}\int_{\alpha_{on}}^{\beta} i_c(\omega t)\sin n\omega t\, \mathrm{d}(\omega t) = \frac{2}{\pi}\omega C U_m \int_{\alpha_{on}}^{\beta} \cos\omega t \sin n\omega t\, \mathrm{d}(\omega t) = 0. \tag{4}$$

For $n=1$, from equations (3), (4), we obtain

$$a_1 = \frac{\omega C U_m}{\pi}(2\beta + \sin 2\beta), \tag{5}$$

$$b_1 = 0. \tag{6}$$

Reactive power based on the main harmonic according to [17]:

$$Q_1 = \frac{U_m I_{1m}}{2}\sin\varphi_1, \tag{7}$$

where I_{1m} is the amplitude of the main harmonic current, φ_1 is the angle of displacement of the main harmonic current relative to the supply voltage.

For the current of the capacitor, taking into consideration expressions (5), (6), we obtain

$$I_{1m} = \sqrt{a_1^2 + b_1^2} = \frac{\omega C U_m}{\pi}(2\beta + \sin 2\beta), \tag{8}$$

$$\varphi_1 = \operatorname{arctg}\left(\frac{b_1}{a_1}\right) = \frac{\pi}{2} = \mathrm{const}. \tag{9}$$

Hence the important conclusion: in mode 1, the voltage regulator operates with a constant angle φ_1, the value of which does not depend on the angle β of control of thyristors. According to (7), taking into consideration (8), (9), we obtain that the battery of capacitors generates reactive power according to the main harmonics

$$Q_1 = \frac{U_m^2 \omega C}{2\pi}(2\beta + \sin 2\beta). \tag{10}$$

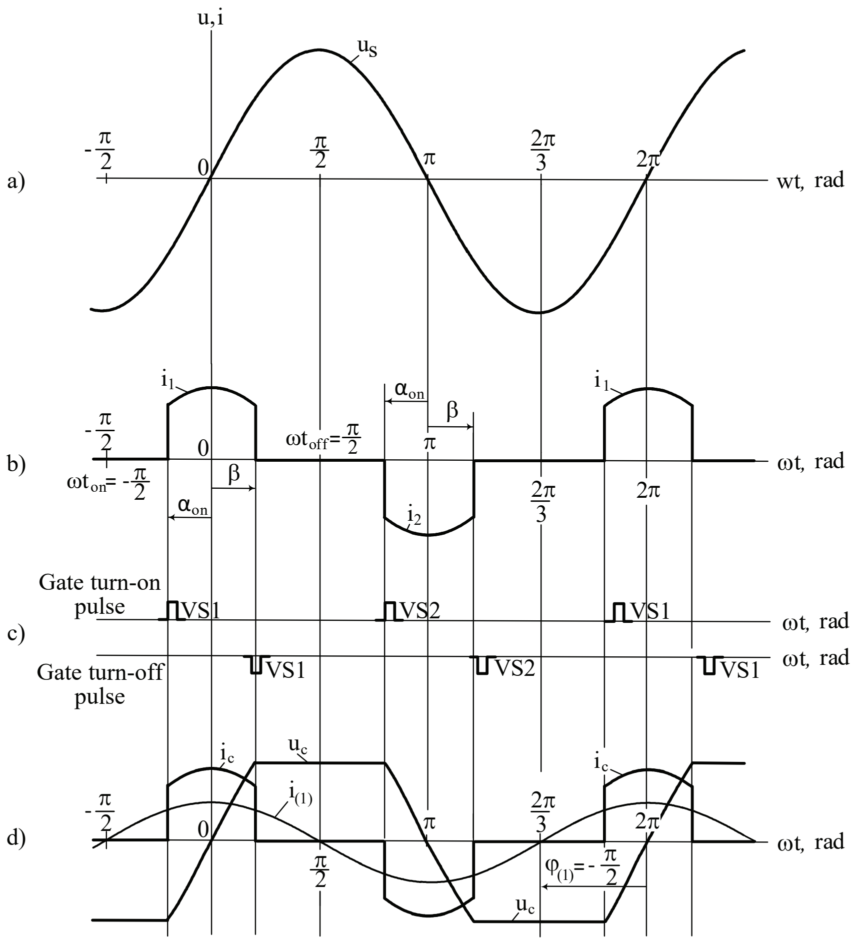

Fig. 2. Time diagrams of the voltage regulator with capacitive load in mode 1 of control of the regulator's thyristors: *a* — power supply voltage; *b* — currents of thyristors; *c* — pulses of thyristor state management; *d* — voltage and capacitor current

Fig. 3 shows the dependence of the relative value of the reactive power $Q_{1*}=Q_1/Q_b$ calculated by formula (10) generated by the battery on the value of the closing angle β of the regulator's thyristors.

Its base power is taken for β=π/2, that is, $Q_b = U_m^2 \omega C / 2$.

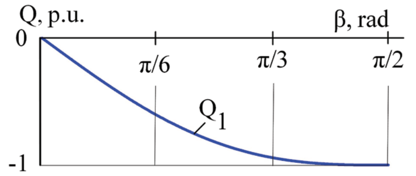

Fig. 3. Angular characteristics of reactive power according to the main harmonics for mode 1 of the voltage regulator

5. 2. Results of modeling a phase control mode of single-operation thyristors of voltage regulator with capacitive load

To implement mode 2 of the phase control of the thyristors of the voltage regulator, single-operation thyristors are suitable (Fig. 4).

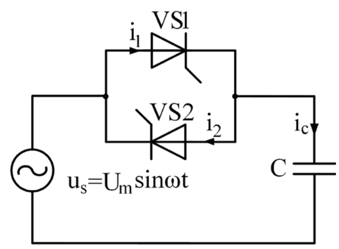

Fig. 4. Equivalent voltage regulator phase diagram with single-operation thyristors

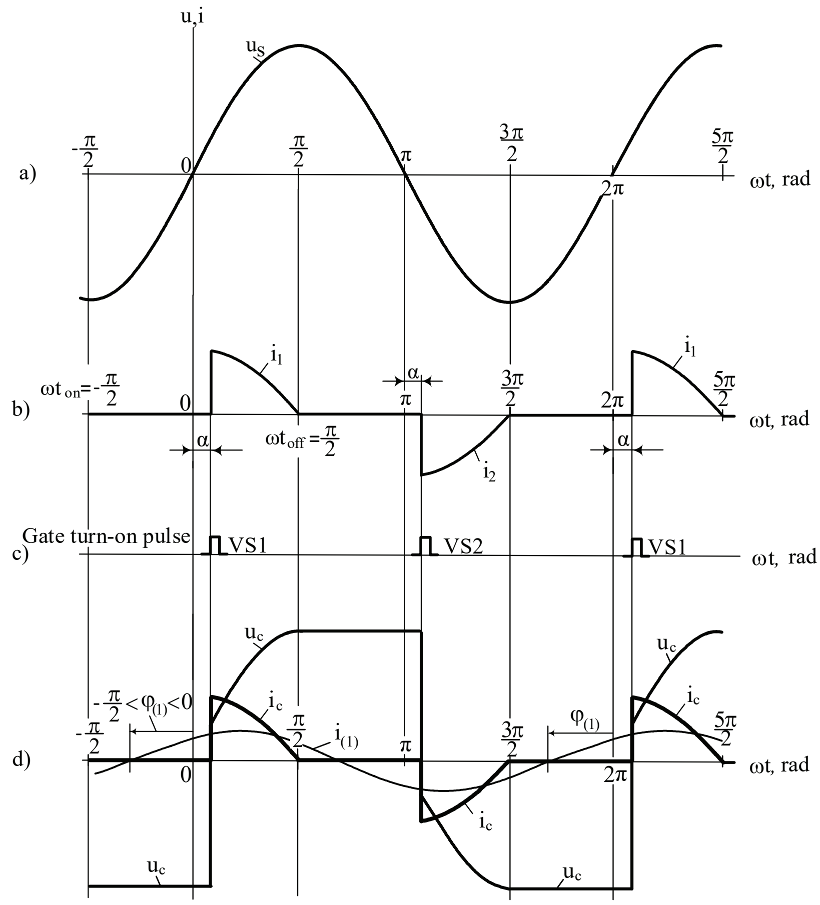

Fig. 5. Time diagrams under mode 2 of control of thyristors of the voltage regulator: *a* – voltage of the power supply; *b* – currents of thyristors; *c* – pulses of thyristor state management; *d* – voltage and capacitor current

Time diagrams of voltages and currents illustrating electromagnetic processes characteristic of the 2nd phase control mode of the regulator's thyristors with capacitive load are shown in Fig. 5. The thyristor *VS*1 is opened by the control impulse at a given time α with a delay relative to the natural moment of its opening time $\omega t_{on}=-\pi/2$, and it closes independently at the natural time of closing $\omega t_{off}=\pi/2$ (Fig. 5, *b*). The total range for changing the thyristor control angles is $-\pi/2 \le \alpha \le \pi/2$, that is $|\alpha|=0 \div \pi$ rad. Thus, the thyristors of the regulator under mode 2 are carried out with a given angle of their opening, but the unchanging angle of their closing, so the duration of the conductive state of each thyristor is $\delta=\pi/2-\alpha$.

At the interval of the conductive state of the thyristor *VS*1 $00 \le \alpha \le \pi/2$ (Fig. 3), the current in the capacitor is described by equation (1). To obtain an energy regulator, decompose the i_c current into a Fourier series. As a result, we get the following expressions for the coefficients of the series:

$$a_n = \frac{2}{\pi}\int_{\alpha}^{\frac{\pi}{2}} i_C(\omega t)\cos n\omega t \,\mathrm{d}(\omega t) =$$

$$= \frac{2}{\pi}\omega C U_m \int_{\alpha}^{\frac{\pi}{2}} \cos\omega t \cos n\omega t \,\mathrm{d}(\omega t) =$$

$$= \frac{1}{\pi}\omega C U_m \left\{ \begin{array}{l} \dfrac{\sin\left[(1-n)\dfrac{\pi}{2}\right] - \sin\left[(1-n)\alpha\right]}{1-n} + \\ + \dfrac{\sin\left[(1+n)\dfrac{\pi}{2}\right] - \sin\left[(1+n)\alpha\right]}{1+n} \end{array} \right\}. \quad (11)$$

$$b_n = \frac{2}{\pi}\int_{\alpha}^{\frac{\pi}{2}} i_c(\omega t)\cos n\omega t \,\mathrm{d}(\omega t) =$$

$$= \frac{2}{\pi}\omega C U_m \int_{\alpha}^{\frac{\pi}{2}} \cos\omega t \cos n\omega t \,\mathrm{d}(\omega t) =$$

$$= \frac{1}{\pi}\omega C U_m \left\{ \begin{array}{l} \dfrac{\cos\left[(1-n)\alpha\right] - \cos\left[(1-n)\dfrac{\pi}{2}\right]}{1-n} + \\ + \dfrac{\cos\left[(1+n)\alpha\right] - \cos\left[(1+n)\dfrac{\pi}{2}\right]}{1+n} \end{array} \right\}. \quad (12)$$

For n=1, from equations (11), (12), we obtain expressions for the coefficients of the main harmonics of the Fourier series:

$$a_1 = \frac{\omega C U_m}{2\pi}(\pi - 2\alpha - \sin 2\alpha), \quad (13)$$

$$b_1 = \frac{\omega C U_m}{2\pi}(1 + \cos 2\alpha). \quad (14)$$

The amplitude and phase of the main harmonic current, respectively

$$I_{1m} = \sqrt{a_1^2 + b_1^2}, \quad (15)$$

$$\varphi_1 = \operatorname{arctg}\left(\frac{b_1}{a_1}\right). \tag{16}$$

Calculated by expressions (13), (14), (15), (16), the dependence of the angle of displacement of the main harmonic current relative to the voltage of the power supply on the angle of delay in opening the thyristors of the regulator is shown in Fig. 6.

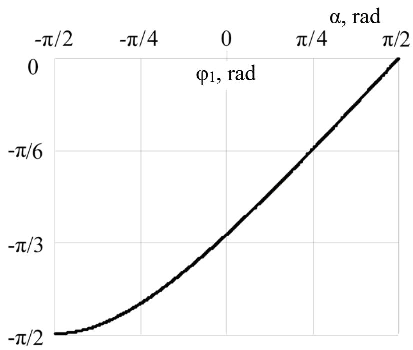

Fig. 6. Angle φ_1 of the displacement of the main harmonic current during adjusting the angle α

The resulting value of the angle φ_1 in the range of values $-\pi/2 \le \varphi_1 \le 0$ means that the capacitor, which is powered by the thyristor AVR under mode 2, consumes from the power supply an active power component according to the main harmonics, which can be calculated using the following formula from [17]:

$$P_1 = \frac{U_m I_{1m}}{2}\cos\varphi_1. \tag{17}$$

Fig. 7 shows the dependence of reactive and active power on the main harmonics for mode 2 of the phase control of the regulator's thyristors on the control angle of the thyristors, calculated using formulas (11) to (17).

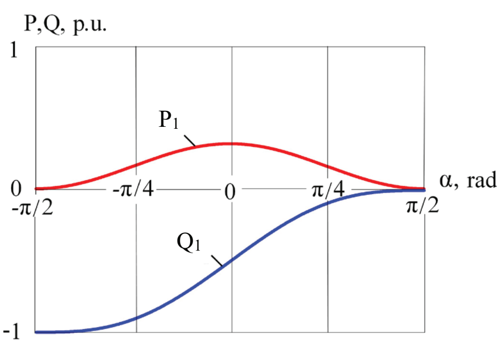

Fig. 7. Angular characteristics of reactive Q_1 and active P_1 power according to the main harmonics for mode 2 of the voltage regulator

The maximum consumption of active power is 0.32 p.u. and is observed at the control angle α=0 since, in this case, the delay in opening the thyristors at angle π/2 rad compensates for the value of the natural angle $\omega t_{on}=-\pi/2$ ahead of the main harmonics of the capacitive current component.

During the mathematical modeling of electromagnetic processes of the voltage regulator mode with phase control of single-operation thyristors, which feeds the capacitive load, the phenomenon of loading the power supply with the active component of power was revealed. This circumstance requires explanation and experimental confirmation since the flow of active power is detected mathematically in a lossless network with ideal key elements. It is known that in AC electrical circuits, active power characterizes the intensity of work on converting electrical energy into thermal, light, or mechanical energy.

To illustrate the manifestation of active power under mode 2 of AVR with capacitive load, a study of the mode of the power station unit was carried out. Turbine T drives the rotor of the three-phase synchronous generator GS, from which it receives the static active load *R*. The CB capacitor battery, adjustable by single-operation thyristors *VS*1, *VS*2 using the CS control system (Fig. 8), can be connected to the generator's buses by the switching device Q.

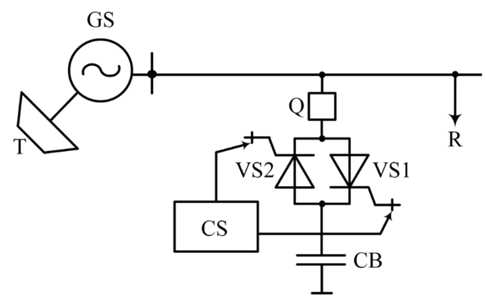

Fig. 8. Schematic diagram of the electrical system

To conduct an experimental study of the electrical system (Fig. 8), a corresponding model was developed in the Simulink visual programming environment of the MATLAB package of application programs for modeling, imitation, and numerical analysis of dynamic systems (Fig. 9).

The generator model, with a rated capacity of 187 MBA, a frequency of 60 Hz, and a voltage of 13.8 kV, together with the means of measuring and visualizing the mode of operation, are borrowed from the SimPowerSystem software library for applied tasks on electricity in the Simulink environment [17].

The essence of the computer experiment is to track the effect of a thyristor-adjustable capacitor battery on electromagnetic power and voltage frequency on the outputs of an unregulated synchronous generator, the time charts of which are shown in Fig. 10. At the time t=0, the synchronous generator, the rotor of which is driven by a turbine with a capacity of 2.5 MW, is turned on for a three-phase active static load with a capacity of 1 MW. The regime is characterized by unbalanced generation and consumption, with a value of 1.5 MW. Under the influence of an excess of generation power over a time interval of 0.5 s, the voltage frequency increases from 60 Hz to 60.05 Hz (Fig. 10, *a*). At the time t_1=0.5 s, a three-phase shunt capacitor battery with a capacity of 70 μF, controlled by thyristors with opening angles $\alpha=-\pi/6$ rad, is turned on. As a result, the loading of the generator with an active capacity increases from 1 MW to 5 MW (Fig. 10, *b*).

Thus, the input into operation of an adjustable shunt capacitor battery by energy effect is equivalent to connecting an additional active load of 4 MW. Next, under the influence of a shortage of generation power (2.5 MW), the frequency value in the system begins to decrease. At the time t_2=1.0 s, when the frequency decreased to a level below 60 Hz, the capacitor battery is switched off and, under the influence of an excess of generation power, the frequency begins to increase again.

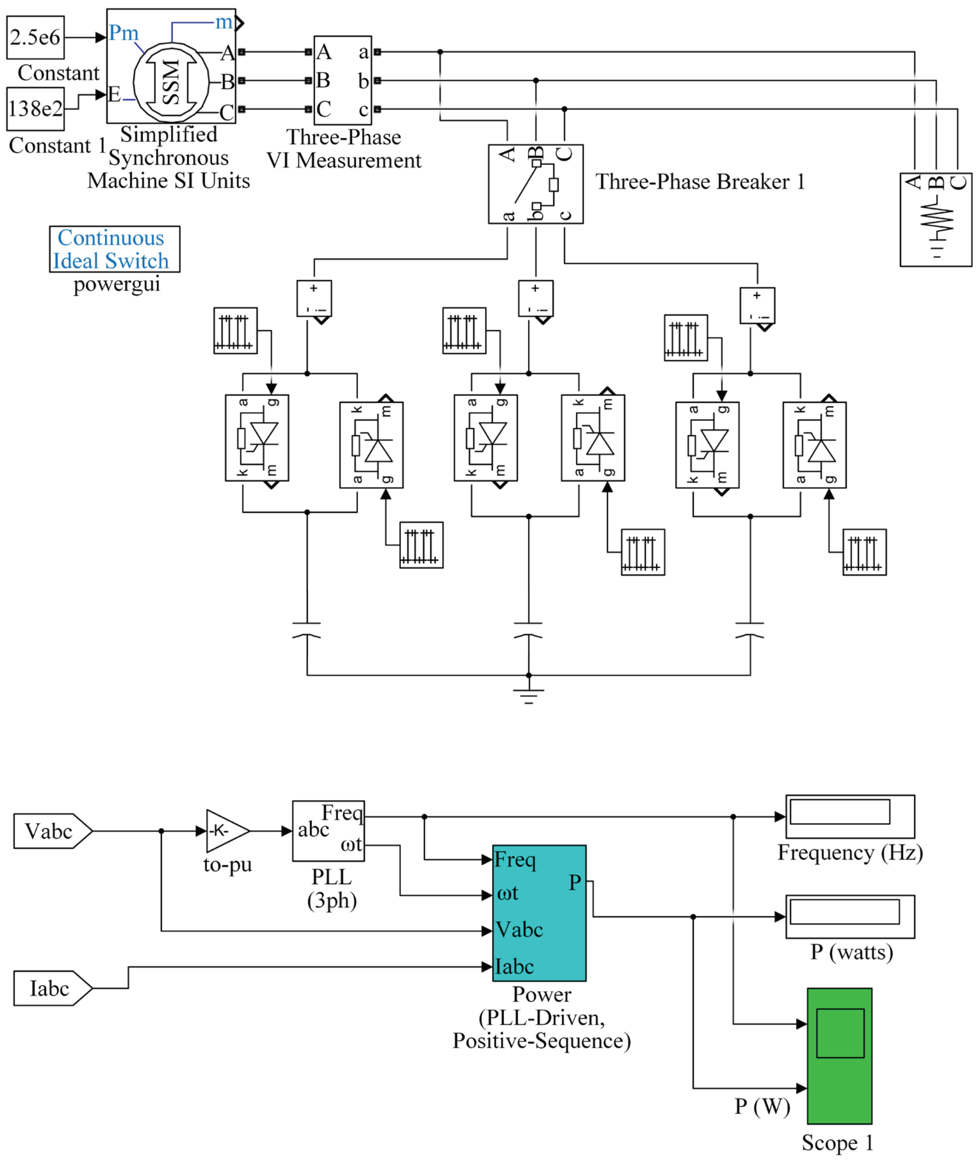

Fig. 9. Simulink model of power system with thyristor-adjustable capacitor battery

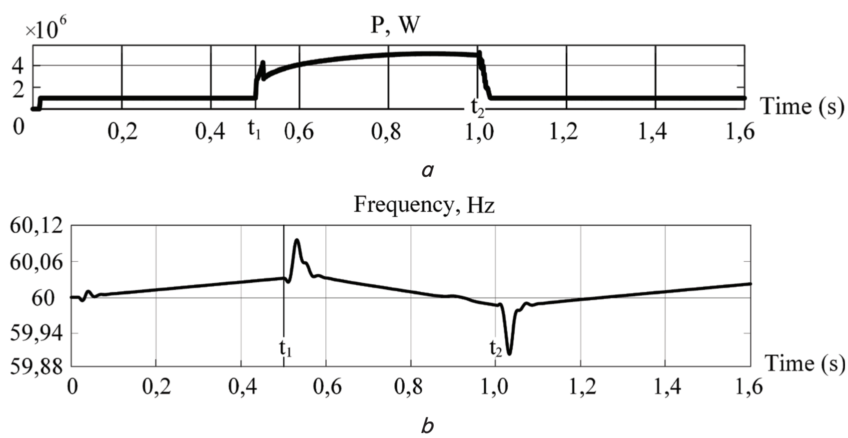

Fig. 10. Time charts of synchronous generator mode parameters: *a* – active power according to the main harmonic; *b* – frequency

6. Discussion of studying the voltage regulator with capacitive load

The advantage of the investigated technique of phase voltage regulation based on the use of fully controlled semiconductor gates is the ability to obtain a thyristor-adjustable capacitor unit with direct adjustment of reactive power. Unlike thyristor-switched capacitor batteries, the adjustment of which requires the presence of thyristor-adjustable shunt reactors. Our solutions are confirmed by a calculated angular characteristic for reactive power (Fig. 3). At the angles of preemptive closing of thyristors, before the natural time of their closing ($\beta<\omega t_{off}=\pi/2$), as shown in Fig. 2, *b*, there is a corresponding shift towards the delay of the moments of their natural opening. We have mathematically derived $|\alpha_{on}|=|\beta|$, zero value of the sine coefficient of decomposition into a Fourier series (formula (6) and the unchanging value of the angle of displacement of the main harmonic current relative to the power supply voltage ($\varphi_1=\pi/2$).

The study of the mode of operation of AVR with phase regulation by single-operation thyristors revealed a new effect of theoretical significance and important from the point of view of power theory for energy electronics devices. In the system without losses, the phase thyristor adjustment mode with a reactive element (capacitor) is characterized by the appearance of an active component of current (power) (Fig. 6). Increasing the angle α of delay in opening thyristors at a fixed angle of their closing $\omega t_{off}=\pi/2$ leads to a decrease in angle φ_1 and the current in the capacitor instead of the capacitive nature becomes active-capacitive. In contrast to the technique of adjusting the AVR by specifying the closing angles of thyristors, for which in the process of adjusting the angle the value φ_1=const.

Our result is somewhat similar to that reported in [13, 14] where it is shown how for a resistive system without reactive elements with the help of ideal semiconductor gates, you can get the reactive power of both signs.

To understand the essence of the appearance of the active component of power in the circle of the capacitor battery, adjustable by single-operation thyristors, its effect on the voltage frequency and rotation speed of the rotor of the synchronous generator is investigated. The activation of the capacitance, powered by the thyristor voltage regulator, leads to the appearance of an additional component of the electromagnetic moment of the synchronous generator and contributes to its braking. This is a manifestation of loading the generator with active power in the main harmonics. That is, in this case, the thyristor-adjustable capacity consumes the active component of the power.

Confirmed by mathematical modeling, the active component of power during phase regulation of the capacitor battery with single-operation semiconductor gates requires a terminological definition, which is associated with the conditions for its derivation.

The component of active power in the electric circuit at a non-sinusoidal current in [18, 19] is called active power by the main harmonic. Paper [20] introduces the term “reactive shear power”. It is proposed to call the resulting active component of the power “active power of artificial displacement” since its occurrence in the system without losses is due to the thyristor displacement of the phase of the main harmonic current relative to the supply voltage. This is the result of external exposure to voltage and power current. By analogy, reactive power in the main harmonics in a resistive electric circuit with controlled semiconductor gates [13, 14], in addition to [20], can be called “reactive power of artificial shear”.

The disadvantage, which should be taken into consideration in attempts to practically apply the investigated techniques of phase regulation of alternating voltage on a capacitor battery, is the possibility of complex switching transition processes. They can be caused by the redistribution of energy reserves between the capacitor battery capacity and the inductance of elements of the electrical network. In each case, separate studies should be carried out and the limit values of the regime parameters should be identified. For example, restrictions may be imposed on the ranges of angles of control of gates, the degree of compensation for reactive power, or there may be a need for the use of certain protective equipment, etc. Another disadvantage of the study is the lack of assessment of the distortion power as a component of full power for the case of a non-sinusoidal form of current [19].

This study may be advanced via the assessment of the parameters of transients and by determining the levels of electromagnetic compatibility and the impact on the quality of electrical energy in the power supply system with phase thyristor regulation of the capacitor battery based on AVR.

7. Conclusions

1. The use in semiconductor voltage regulators of two-operation thyristors, controlled by their advanced closure, makes it possible to create a thyristor-adjustable capacitor battery as a direct, smooth, and quickly adjustable reactive power source.

2. Under the phase control mode, the conductive state of single-operation thyristors of the voltage regulator with a capacitive load revealed the phenomenon of consumption from the power supply network of the active component of power, which is called the active power of artificial displacement. The maximum consumption of active power is 32 % of the rated power of the capacitor battery.

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