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A STRUCTURE OF A SYNCHRONOUS GENERATOR EXCITATION SYSTEM TO STABILIZE THE OUTPUT VOLTAGE WITH FREQUENCY FLUCTUATIONS

СТРУКТУРА СИСТЕМИ ЗБУДЖЕННЯ СИНХРОННОГО ГЕНЕРАТОРА ДЛЯ СТАБІЛІЗАЦІЇ ВИХІДНОЇ НАПРУГИ ПРИ КОЛИВАННЯХ ЧАСТОТИ

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At the present stage of development of autonomous, including ship electric power, there is a need for a transition to energy-saving technologies – various ways to reduce electrical energy losses [1, p. 407; 2, p. 206; 3, p. 79]. There are operating modes of ship electric power plants (SEPP), in which the generator operates in parallel with the onshore network, or in parallel with other generators [4, p. 373]. In such operating modes, it is necessary to solve the problem of maintaining a given value of the power factor [5, p. 4728]. A change in the generator excitation current leads to the appearance of reactive power generated or consumed from the electrical network [6, p. 64]. The total power of generators in SEPP is significantly less than for stationary electric power plants. Therefore, in SEPP, switching of electricity consumers, such as powerful asynchronous motors, leads to a change in the frequency of the voltage in the ship's network, which, in turn, affects the RMS value of the voltage in the network, affects the quality of electricity and leads to the occurrence of reactive power flows between generators.

The aim of the research is to improve the method for adjusting the output voltage of a ship synchronous generator with frequency fluctuations and to develop the structure of the corresponding control system, which is presented in the form of a graphical-analytical model. The proposed method of adjusting the output voltage consists of changing the moments of time when the control pulses to the thyristors of the excitation system are formed. The moments of forming the control pulses depend on changes of the network voltage frequency. This ensures stabilization of the generator reactive power and leads to fuel savings of 5–10 %.

The proposed method for controlling the excitation of a synchronous generator when the frequency of the output voltage fluctuates is that the generator output voltage U_{out} is converted into the analog signal ΔU_{out} by means of the functional structure $f(\pm U_{out}, |\Delta U_{out}|)$. Next, a subsequent conversion occurs and its comparison with the reference voltage U_k in the functional structure of the comparator $f_1(|\Delta U_{out}|<U_k)$. A control signal is also generated, which, after amplification, is sent to a ring pulse distributor. This pulse distributor generates serial control signals $U_{\varphi 1.n}$, $U_{\varphi 2.n}$ and $U_{\varphi 3.n}$, where «n» is a continuous sequence of specific values of analog control pulse signals in the functional structure of a demultiplexer f(Demux). The magnitude of the reference analog signal U_k is chosen no higher than the linear part of the converted analog signal $|\Delta U_{out}|$ of a synchronous generator and active analog output signal $U_{\Delta t}\uparrow$ with duration Δt. In the functional structure of the comparator $f_1(|\Delta U_{out}|<U_k)$ only linear part of the converted analog signal is used $|\Delta U_{out}|$. This signal activates the functional structure of the analog-to-digital converter f_1(ADC) to form the structure of analog signals $[U_j]_{out}$. In addition, the structure of analog signals of the voltage change rate, which is caused by fluctuations in the frequency of the network voltage, is also formed using a functional differentiation structure f(d/dn). After this, a logical subtraction is performed from the predetermined structure of analog signals $^0[U_j]_{out}$ f_2(d/dn) via the adder functional structure $f_1(\Sigma)$ to form the resulting sign (+U/-U)f_1(d/dn) and the value of derivative $[U_j]f_1$(d/dn). This makes it possible to adjust the moment at which the formation of successive control pulses $U_{\varphi 1.n+1}$, $U_{\varphi 2.n+1}$ and $U_{\varphi 3.n+1}$ begins in the functional structure of a demultiplexer f(Demux) with an advance or lag relative to the beginning of the formation of the previous sequence of control pulses $U_{\varphi 1.n}$, $U_{\varphi 2.n}$ and $U_{\varphi 3.n}$. The logical-dynamic process of stabilizing the voltage, and as a consequence, the reactive power of the synchronous generator is carried out in accordance with the mathematical model of the form presented in Fig. 1.

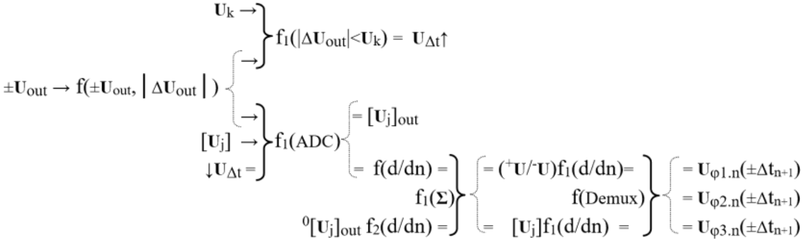

Fig. 1

The figure indicates: f_1(ADC) – functional structure of an analog-to-digital converter; $f_1(\Sigma)$ – functional structure of the adder; f(d/dn) – functional structure of logical differentiation; f(Demux) – functional structure of a demultiplexer.

The proposed method of controlling the excitation of a synchronous generator when the frequency of the output voltage fluctuates is implemented as follows. In accordance with the analytical expression presented in Fig. 2, the output voltage U_{out} of the synchronous generator is converted through the functional structure $f(\pm U_{out}, |\Delta U_{out})$ into an analog signal of the same sign $|\Delta U_{out}|$.

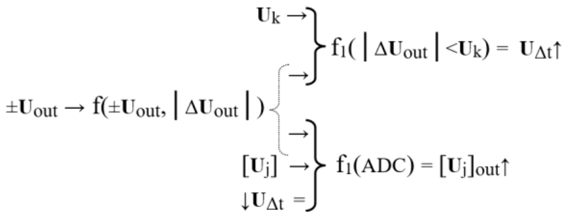

Fig. 2

Then, the converted analog signal is simultaneously passed to the functional structure f_1(ADC) with the reference analog signals $[U_j]$, where «j» is a number of information logical analog signals, and the functional comparison structure $f_1(|\Delta U_{out}|<U_k)$ with analogue reference signal U_k. Then, in accordance with the functional structure presented in Fig. 3, the structure of analog signals is formed.

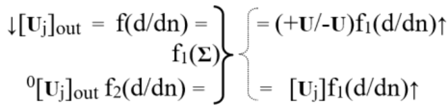

Fig. 3

In accordance with the functional structure presented in Fig. 4, formed in accordance with Fig. 3 logical signal $\downarrow(+U/-U)f_1(d/dn)$ and logic analog signals $\downarrow[U_j]f_1(d/dn)$, and an adjustment is made to the moment at which the formation of successive control pulses $U_{\varphi 1.n+1}$, $U_{\varphi 2.n+1}$ and $U_{\varphi 3.n+1}$ begins in the functional structure of a demultiplexer f(Demux).

$$\left.\begin{array}{r}\downarrow(+\mathbf{U}/\text{-}\mathbf{U})f_1(d/dn) = \\ f(\text{Demux}) \\ \downarrow[\mathbf{U}_j]f_1(d/dn) = \end{array}\right\} \left\{\begin{array}{l} = \mathbf{U}_{\varphi 1.n}(\pm\Delta t_{n+1}) \\ = \mathbf{U}_{\varphi 2.n}(\pm\Delta t_{n+1}) \\ = \mathbf{U}_{\varphi 3.n}(\pm\Delta t_{n+1}) \end{array}\right.$$

Fig. 4

To form a mathematical model of a functionally complete logical-dynamic process of sequential adjustment of the excitation current of a synchronous generator to stabilize its reactive power, the functional structures presented in Fig. 2 – Fig. 4 were combined. In Fig. 5 the structure of the excitation system of a synchronous generator, which implements the described method of stabilizing the output voltage, is presented in graphic-analytical form.

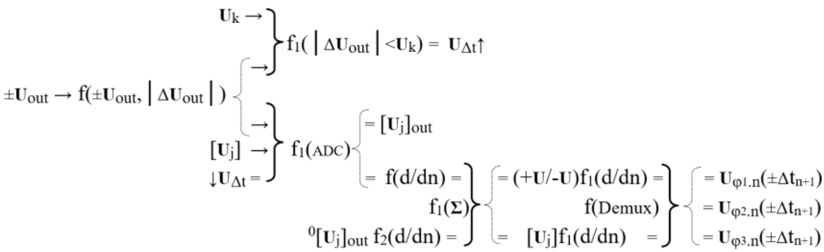

Fig. 5

The use of the proposed technical solution for controlling the excitation of a synchronous generator will make it possible to increase the stability of the output voltage when the frequency in the network fluctuates, to reduce the flow of reactive power between generators when they operate in parallel on a common load, which will ultimately lead to increased energy efficiency of the ship electric power system.

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