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Ushkarenko O.O.
Admiral Makarov National University of Shipbuilding

SYNTHESIS OF A POWER FACTOR CONTROL SYSTEM FOR PARALLEL OPERATION OF SYNCHRONOUS GENERATOR WITH A NETWORK

In the paper the synthesis of a controller based on fuzzy logic to stabilize the power factor through the control of excitation of a synchronous generator that operates in parallel with the network. To achieve the aim of the research a method for the synthesis of a graphic-analytical form of representation the procedure for converting information arguments in the functional structures of control systems objects as parts of autonomous electric power systems has been used. It made it possible to form a mathematical model of the power factor control system and to analyze the system by means of multilevel decomposition to get all the necessary information about the basic properties of its elements from the standpoint of a general systemic approach. In turn, the analysis of signal conversion processes at various levels of decomposition in the control system enabled to study its structural properties and draw a conclusion about the optimality of its structure. When designing a control system, methods of fuzzy logic theory have been used, which made it possible to consider to the fullest extent the phenomenon of interconnectedness and nonlinearity of processes in autonomous power stations. The model of the power station and simulation results of the regulator have been developed. On the basis of the performed modeling, a comparative analysis of the quality of power factor control using three types of controllers – a fuzzy controller, a three-position controller and a PID-controller has been carried out. It was found that the best indicators of the control quality are provided by the controller based on fuzzy logic. The use of the proposed control system makes it possible to increase the energy efficiency of the autonomous and ship electric power systems by implementing such a control strategy in which synchronous generators operate in optimal modes.

Key words: *power factor, synchronous generator, control system, fuzzy logic, simulation.*

Formulation of the problem. The complexity of modern power supply systems and the increasing requirements for the quality of electrical energy in such systems pose the challenge of a thorough study of autonomous electric power systems (AEPS), which also includes ship electric power systems (SEPS), at various design stages. A continuous increase in AEPS capacity is a regular trend. An increase in SEPS capacity, in turn, complicates the procedure of ensuring a given quality of electricity [1, p. 866].

An autonomous electric power system is a set of interconnected electric power generators, converters, distribution, regulatory and control devices, as well as connecting cables and consumers. A current challenge is to reduce the cost of electricity generation, which can be achieved by reducing the amount of fuel consumed by diesel engines, as noted in [2, p. 24]. Electricity consumers are designed to operate at nominal parameters that ensure their high efficiency factor, reliability indicators, and continuous trouble-free operation time. The modern development of computer communication systems, data processing, and automatic control systems for operating procedures and production complexes poses increased requirements for both the reliability of power supply and the quality of electricity [3, p. 6].

Analysis of recent research and publications. There are operation modes of AEPS and SEPS in which the generator operates in parallel with the network, for instance, in cogeneration units [4, p. 365]. Additionally, ship electric power systems, when docked in port, are connected to parallel operation with the coastal network. In such operation modes, it is required to solve the problem of maintaining an optimal power factor value for this mode [5, p. 19]. This problem is partially solved by using power distribution devices, though the power factor depends on both active and full power, which is also affected by the reactive power value. It is considered that the network power is much higher than that of the generator. At a given active power produced by the generator, the variation in the generator excitation current leads to a variation in the reactive power supplied to or consumed from the network [6, p. 63]. Reactive power generation is carried out both by AEPS generators and by high-voltage overhead and cable transmission lines (due to their capacitive susceptance), as well as by specially installed reactive power sources, also called "compensating devices" [7, p. 2; 8, p. 121]. This, in turn, leads to the cosφ power factor variation. To maintain a given power factor, one should develop a control system that would manage the synchronous generator excitation and maintain the cosφ value at a desired level.

The reactive power balance is generally calculated for the highest load mode. The reactive power that is produced by power plant generators is determined by their loading with active power and the power factor (cosφ), whose nominal value is about 0.8. Generators are the basic sources of reactive power and produce about 60% of the reactive power in SEPS.

Since there is a dependence of consumed reactive power on the voltage, it is evident that there is an inverse dependence between these values. The variation in the reactive power value supplied to the unit causes a variation in the load in this unit. Therefore, the required voltage level in separate units of the electrical network can be ensured only by a separate distribution of reactive powers. Any deviation from the given distribution of reactive powers causes a deviation of the unit network voltage from the required level [9, p. 4]. The diesel-generator unit's nonlinearity requires variation of the parameters of the excitation control pulses to ensure the best control quality in various operating modes. To solve this problem, the fuzzy logic math apparatus can be used.

When solving problems of improving electricity quality in SEPS, simulation along with computational models is widely used. Currently, it is not possible to create universal SEPS models that adequately reflect their properties in various operation modes [10, p. 13]. Thus, specialized math models describing separate procedures in SEPS are considered.

At present, when solving control problems in the autonomous electric power industry, the fuzzy logic apparatus is widely used. In [11, p. 2156], the efficiency of using a controller based on fuzzy logic to control the power flow for a solar-wind energy hybrid system is shown. In [12, p. 1252], a hybrid soft-computing methodology approach for intelligent maximum power point tracking techniques of a photovoltaic system under any expected operating conditions using artificial neural network-fuzzy is considered. In [13, p. 2044], the fuzzy logic apparatus was successfully applied to increase the technical performance of multi-machine systems, which are controlled using a direct torque control method. Thus, as a result of the analysis of scientific publications, it can be concluded that fuzzy logic controllers can be successfully used to improve the quality of control and energy efficiency of autonomous and ship electric power systems. At the same time, these works do not consider the issues of controlling the reactive power of a synchronous generator during their parallel operation for a common load, which also confirms the relevance of this research.

Task statement. This research is devoted to the development of an electricity quality improvement system by controlling the power factor when a synchronous generator operates in parallel with the network. The power factor control is achieved by adjusting the synchronous generator excitation. The quality of power factor control using a three-position controller, a PID-controller, and a fuzzy logic-based controller is considered.

Currently, there are systems and improved methods for distributing active and reactive power between generators operating in parallel on a common load. Such systems are produced by many foreign companies. The feedback in these systems is provided for active and reactive powers respectively [14-17]. When there is a load variation in the AEPS and SEPS, a proportional load sharing between the generators is done. Thus, the generators' power factor may have a non-optimal value. Therefore, the problem of synthesizing a control system that maintains the generator's cosφ at a desired level is relevant.

Outline of the main material of the study. A characteristic feature of the established operating mode of the electric power system is the simultaneity of the processes of generating and consuming the same amount of power. Consequently, in the established operating mode of the AEPS, the balance of both active and reactive powers is maintained at each moment of time [18, p. 3]. When the voltage decreases to about $0.85U_{\text{rated}}$, the reactive power is reduced due to a decrease in the magnetizing capacity of induction motors and transformers. On further decrease in voltage, the induction motors making up to 60-70% of the complex load, start to slow down due to their torque reduction. The reactive power consumed by these motors is being increased. Resulting from an increase in reactive power consumption, the voltage drop in the network is increased, leading to a further decrease in the on-load voltage [19, p. 97]. Thus, it is necessary to develop a system controlling the synchronous generator excitation to maintain a given cosφ. It should also be noted that the known methods of reactive power control that are used in solar power plants, in particular, those discussed in [20, p. 1713; 21, p. 2169], are not applicable to diesel-generator power plants. This is due to the fact that inverters are used in solar power plants, and photovoltaic elements are inherently non-inertial in nature, they do not participate in regulating voltage or reactive power [20, p. 1716], which cannot be said about synchronous generators as part of AEPS.

The synthesis of a power factor control system of a synchronous generator running in parallel with a network involves the analysis of logical and dynamic procedures of argument conversion in control systems. To do this, the method described in [22, p. 378; 23, p. 319] can be used. Using this method, a mathematical model of the power factor control system is synthesized. To determine the generator power factor value, preliminary in accordance with the analytical expression (1), the output voltage U_{out} and current I_{out} of the synchronous generator are converted using functional structures $f(U_{out},\Delta U_{out})$ and $f(I_{out},\Delta I_{out})$ into analog signals ΔU_{out} and ΔI_{out}. The maximum values of these signals do not exceed the dynamic range of the reference voltage structure $[U_j]$ of the functional structures of analog-to-digital converters $f_1(\text{ADC})$ and $f_2(\text{ADC})$. After this, the converted analog signals of the output voltage ΔU_{out} and current ΔI_{out} are converted to the structure of analog logical signals of the output voltage $[U_j]_{out}$ and the output current $[I_j]_{out}$ by comparing them with the structure of the reference voltages $[U_j]$ using functional structures of the analog-to-digital converters $f_1(\text{ADC})$ and $f_2(\text{ADC})$ that are analyzed using the functional structure $f_\varphi(\Sigma)$. Then, the procedure for calculating the power factor value is performed. At the same time, as a result of analyzing the value of the power factor in the functional structure $f_\varphi(\Sigma)$, the logical structure $[U_j]_{\Delta t}f(U,I_{out}\downarrow\uparrow 0)$ of the analog signals is formed with the duration Δt of the analog signal transition of the output voltage U_{out} and the current I_{out} of the generator through the zero level $U_{out}\downarrow\uparrow 0$.

$$\left.\begin{array}{r}\left.\begin{array}{r}U_{out}\to f(U_{out},\Delta U_{out})\to\\ f_1(\text{ADC})\\ [U_j]\to\end{array}\right\}\begin{array}{l}=[U_j]_{out}\uparrow\\ \\ =[U_j]_{out}=\end{array}\\ \left.\begin{array}{r}[U_j]\to\\ f_2(\text{ADC})\\ I_{out}\to f(I_{out},\Delta I_{out})\to\end{array}\right\}\begin{array}{l}=[I_j]_{out}=\\ \\ =[I_j]_{out}\uparrow\end{array}\end{array}\right\} f_\varphi(\Sigma)=[U_j]_{\Delta t}f(U,I_{out}\downarrow\uparrow 0)\uparrow \quad (1)$$

Simultaneously with this procedure, in accordance with the functional structure (2), using the functional structure $f_1(\text{Sign})$, the structures of analog logical signals of the output voltage $[U_j]_{out}$ and the output current $[I_j]_{out}$ are analyzed, and a logical analog signal of positive value $+U^L$ is generated, corresponding to the inductive reactive power of the generator, or a logical analog signal of negative value $-U^C$ is generated, corresponding to the capacitive reactive power of the generator.

$$\left.\begin{array}{l}[U_j]_{out}=\\ \\ [I_j]_{out}=\end{array}\right\} f_1(\text{Sign})=+U^L/-U^C \quad (2)$$

With the conversions of output voltage U_{out} and the current I_{out} of the synchronous generator, in accordance with the equation (3), reference voltage $U_{\cos\varphi}$ comparison is performed that corresponds to the given cosφ, with the structure of the reference voltages $[U_j]$. This value is converted into the structure of the logical analog signals $[U_j]_{\cos\varphi}$ using the functional structure $f_3(\text{ADC})$. Afterwards, the structure of the logical analog signals $[U_j]_{\cos\varphi}$ is logically added in the functional structure of the integrator $f_1(\Sigma)$ with the structure $\downarrow[U_j]_{\Delta t}f(U,I_{out}\downarrow\uparrow 0)$ of the logical analog signals in the equation (1). As a result, both the logical structure of analog signals $[U_j]_\varepsilon$ of error ε and the logical structure of analog signals $[U_j]_{d\varepsilon}$ of the rate of change d/dn of error ε are formed.

$$\left.\begin{array}{r}\downarrow[U_j]_{\Delta t}f(U,I_{out}\downarrow\uparrow 0)=\\ \left.\begin{array}{r}U_{\cos\varphi}\to\\ f_3(\text{ADC})\\ [U_j]\to\end{array}\right\}=[U_j]_{\cos\varphi}=\end{array}\right\} f_1(\Sigma)\begin{cases}=[U_j]_\varepsilon\uparrow\\ =f(d/dn)=[U_j]_{d\varepsilon}\end{cases} \quad (3)$$

When analyzing the logical structure of the analog signals $[U_j]_\varepsilon$ of the error ε in the equation (4), using the functional structure of the reactive power sign functional structure $f_2(\text{Sign})$, either the second logical analog signal of the positive value $+U^L_2$ corresponding to the inductive reactive power of the generator, or the second logical analog signal of the negative value $-U^C_2$ corresponding to the capacitive reactive power of the generator is formed.

$$\downarrow[U_j]_\varepsilon=f_2(\text{Sign})=(+U^L_2/-U^C_2)\uparrow \quad (4)$$

Afterwards, in accordance with the structure of the logic elements $f_1(\&)$-AND, $f_1(\&)$-NOT and $f_1(\})$-OR in the equation (5), the first and second analog signals $+U^L_1$, $-U^C_1$ and $+U^L_2$, $-U^C_2$ are compared, and the corrected logical analog signals $+U^L_3/-U^C_3$ are formed.

$$\left.\begin{array}{r}\downarrow(+U^L_1/-U^C_1)=\underline{\&}_1\ =\\ \left.\begin{array}{r}\downarrow(+U^L_1/-U^C_1)=1\\ \&_1\ =\\ \downarrow(+U^L_2/-U^C_2)\ =\end{array}\right\}=\end{array}\right\}(+U^L_3/-U^C_3)\uparrow \quad (5)$$

In parallel with the analysis of the logical structure of analog signals $[U_j]_\varepsilon$ of the error ε in accordance with the equation (4), analysis is performed using a fuzzy logic functional structure $f(\text{Fuzzy})$ and a sequence of pulse signals $U(\Delta t,T)$ is generated with a duration Δt and a pulse period T, as shown in (6).

$$\left.\begin{array}{r}\downarrow(+U^{L}_{2}/-U^{C}_{2})=\\ \downarrow[U_j]_{\varepsilon}=\\ \downarrow[U_j]_{d\varepsilon}=\end{array}\right\} f(Fuzzy)=U(\Delta t,T) \qquad (6)$$

To form a mathematical model of a functionally complete logical and dynamic procedure of sequential adjustment of the synchronous generator excitation current to stabilize its reactive power, the equations (1) to (6) are combined. The resulting equation (7) is given below.

$$\begin{array}{l}
\left.\begin{array}{r}I_{out}\rightarrow f(I_{out},\Delta I_{out})\rightarrow\\ f_1(ADC)\\ [U_j]\rightarrow\end{array}\right\}\begin{array}{l}=[I_j]_{out}\uparrow\\ =[I_j]_{out}=\end{array}\\
\left.\begin{array}{r}[U_j]\rightarrow\\ f_2(ADC)\\ U_{out}\rightarrow f(U_{out},\Delta U_{out})\rightarrow\end{array}\right\}\begin{array}{l}=[U_j]_{out}=\\ =[U_j]_{out}=\end{array}\\
\left.\begin{array}{r}[I_j]_{out}=\\ [U_j]_{out}=\end{array}\right\} f_{\varphi}(\Sigma)=[U_j]_{\Delta t}f(U,I_{out}\downarrow\uparrow 0)\uparrow\\
\left.\begin{array}{r}[U_j]_{out}=\\ \downarrow[I_j]_{out}=\end{array}\right\} f_1(Sign)\left\{\begin{array}{l}=(+U^{L}_{1}/-U^{C}_{1})\uparrow\\ =\underline{\&}_1=\end{array}\right.\\
\left.\begin{array}{r}\downarrow(+U^{L}_{1}/-U^{C}_{1})=1\\ \&_1=\\ =(+U^{L}_{2}/-U^{C}_{2})=\end{array}\right\}=\\
\downarrow[U_j]_{\varepsilon}=f_2(Sign)\\
\left.\begin{array}{r}U_{\cos\varphi}\rightarrow\\ f_3(ADC)\\ [U_j]\rightarrow\end{array}\right\}=[U_j]_{\cos\varphi}=\;\;
\left.\begin{array}{r}\downarrow[U_j]_{\Delta t}f(U,I_{out}\downarrow\uparrow 0)=\\ f_1(\Sigma)\\ =[U_j]_{\cos\varphi}=\end{array}\right\}\begin{array}{l}=[U_j]_{\varepsilon}\uparrow\\ =f(d/dn)\end{array}\\
\left.\begin{array}{r}=\\ \downarrow[U_j]_{\varepsilon}=\\ =[U_j]_{d\varepsilon}=\end{array}\right\} f(Fuzzy)=U(\Delta t,T)=\\
\Big\} f(Demux)\left\{\begin{array}{l}=U_{\varphi 1.n}(\pm\Delta t_{n+1})\\ =U_{\varphi 2.n}(\pm\Delta t_{n+1})\\ =U_{\varphi 3.n}(\pm\Delta t_{n+1})\end{array}\right.
\end{array} \qquad (7)$$

The functional diagram of the automatic control system based on a fuzzy logic (control system with a fuzzy regulator) [24, p. 155], which developed in accordance with equation (7), is given in Fig. 1.

The following is indicated on the diagram: Fuzzy regulator – the controller based on fuzzy logic; SC – signals converter; SGExS – synchronous generator excitation system; SG – synchronous generator; PFCB – power factor computing block; ADC – analog to digital converter. The error value "*ε*", equal to the difference between the reference and actual cosφ values, the "*dε*" error variation rate (the first derivative) and the cosφ sign are used as the controller input variables.

For each variable, linguistic terms are specified that correspond to certain ranges of input values. To determine the limiting values of the error *ε*, the probable values of the reference cosφ and the actual cosφ values have been considered. The reference value of cosφ is set, so the optimal value that can be set is cosφ=0.3..1. The actual value of cosφ can take values from 0.3 to 1. Assuming that the error *ε* has the following limits [-0.7...0.7], five terms are used for the "error" (*ε*) input variable: NH – negative high, NL – negative low, Z – close to zero, PL – positive low, PH – positive high.

For the input variable "d(error)" (*dε*), the boundaries are [-0.2..0.2]. Since the rate of change of error can

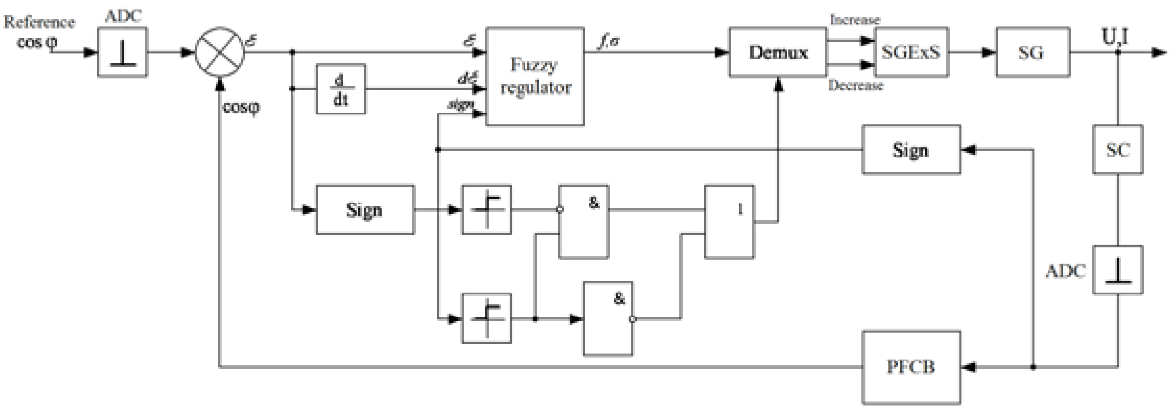


Fig. 1. Functional diagram of power factor control system with a fuzzy logic-based controller

increase and decrease, therefore, an increase in the rate of change can be taken as a positive value, and a decrease as a negative value, respectively. The following terms are defined: QD – quick decrease, SD – slow decrease, C – constant, SI – slow increase, QI – quick increase. Figure 2 represents the membership functions of the "error" and "error variation rate" variable, respectively.

The output signal frequency and duty cycle are taken as output linguistic variables. The "frequency" linguistic variable has [0..4] Hz limits and the following five terms: Z – zero value, L – low value, M1 – first mean value, M2 – second mean value, H – high frequency value. The "duty cycle" linguistic variable has [0%...100%] limits and the following four terms: Z – zero value, L – low value, M – mean value, H – high duty cycle. Fig. 3 represents the membership functions of the "frequency" and "duty cycle" variables, respectively.

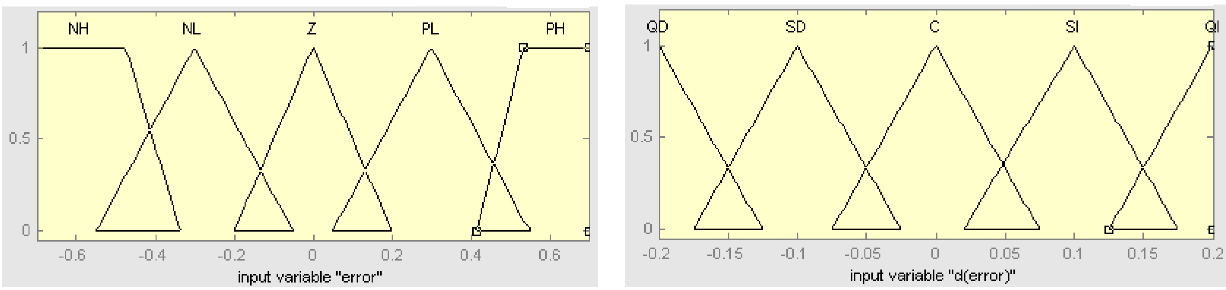
Resulting from simulation, the fuzzy output surfaces of the "frequency" and "duty cycle" dependencies on "error", "error variation rate" and "sign" have been obtained. Fig. 4, a, represents the surface of the "frequency" dependence on ε and $d\varepsilon$ for the inductive nature of the load. Fig. 4, b, represents the surface of the "duty cycle" dependence on ε and $d\varepsilon$ for the inductive nature of the load.

The surface in Fig. 4, a, is symmetrical relative to the origin point. The minimum frequency value is observed in the region ε=0 and $d\varepsilon$=0. The frequency maximums are observed in the area where the "error" and the "error derivative" are both positive high, and in the area where the "error" and the "error derivative" are both negative high. The surface in Fig. 4, b, is mirrored relative to the origin. The minimum area is observed approximately at ε=0. The Matlab model of the AEPS for the research of control processes along with an implemented fuzzy logic-based power factor controller is shown in Fig. 5.

Research on the effectiveness of using a three-position relay controller to manage power factor has been also carried out. Three-position controllers ensure proper control quality for inertial control objects with a small delay [25, p. 06016]. The block diagram of the three-position excitation control system of the synchronous generator is shown in Fig. 6.

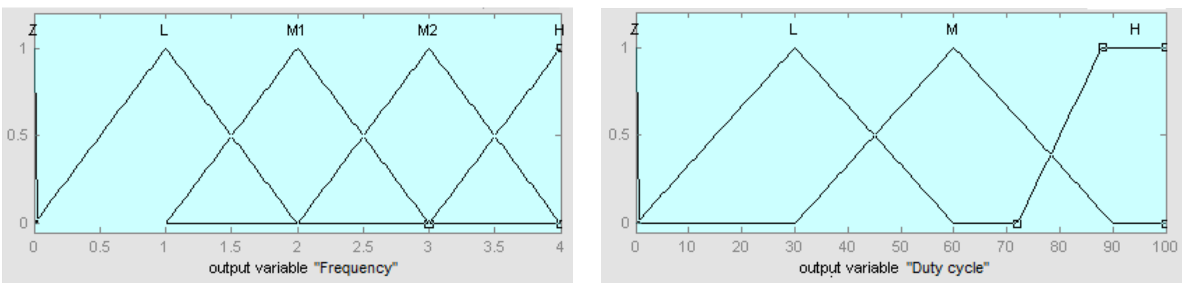
To obtain the best indicators of the power factor control quality, it is necessary to optimize the controller. Such controller parameters as the period of control pulses and their duty cycle are subject to optimization. When optimizing the controller parameters, the integral quality criterion I is minimized. Table 1 represents the values of the integral control quality criterion I at different values of the control pulse interval, as well as at different values of the generator load (25%, 50% and 75% of rated power).

A three-position controlling procedure is self-oscillatory – the controlled value in both transient and



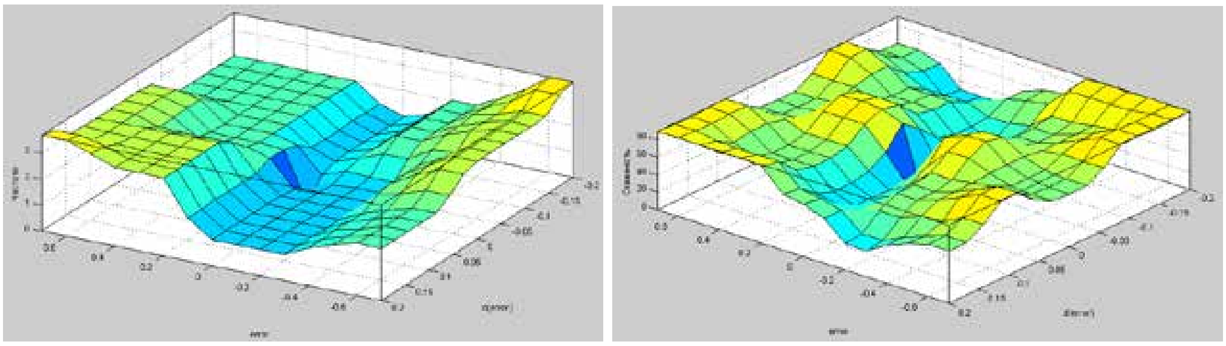
a) b)

Fig. 2. Input variables membership functions: a) "error"; b) "d(error)"



a) b)

Fig. 3. The output variables membership functions: a) "frequency"; b) "duty cycle"



a) b)

Fig. 4. The surface of the "frequency" dependence on *ε* and *dε* for the inductive nature of the load: a) frequency; b) duty cycle

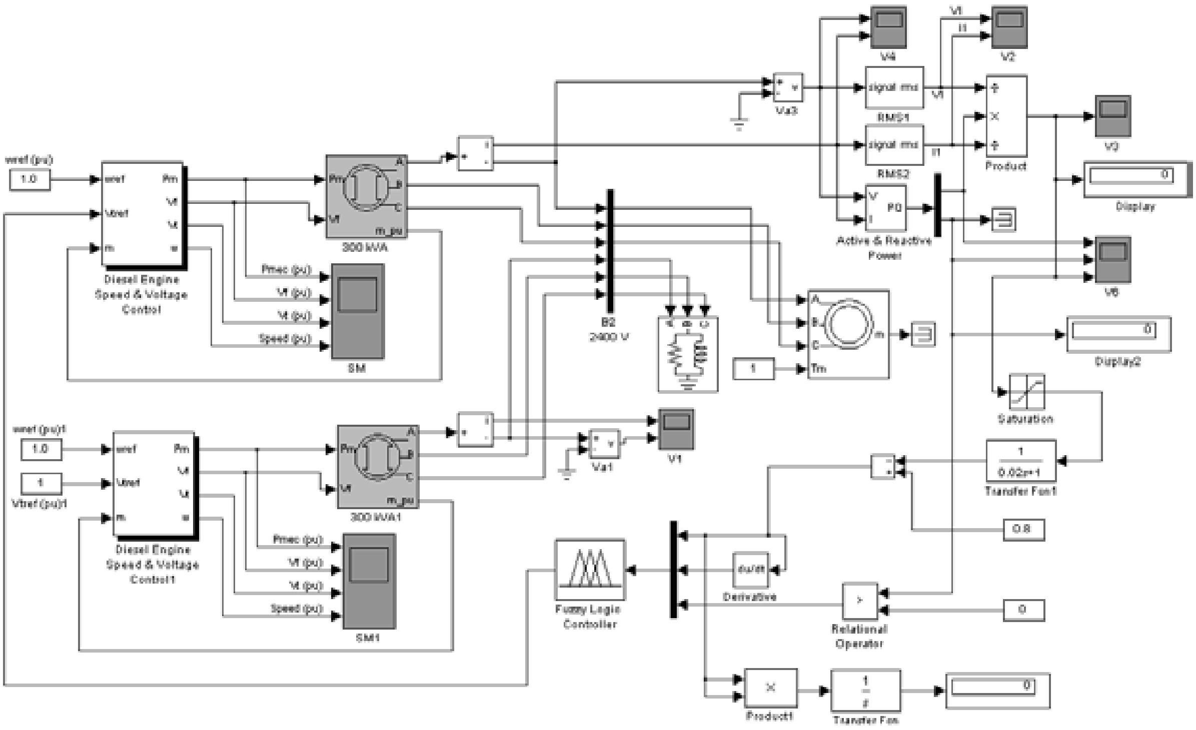


Fig. 5. AEPS Matlab model with power factor fuzzy logic-based controller

steady-state mode periodically changes relative to the reference value. Despite this, as can be seen from Table 1, there are optimal parameters of the controller when *T*=1s. In addition, by setting the width of the controller dead zone, it is possible to ensure stabilization of the power factor within specified limits.

In the block diagram in Fig. 6, instead of a three-position controller, a PID controller with a pulse output can be used. The output control signals of the regulator are discrete signals to increase and decrease the generator output voltage, which are supplied to the SG excitation control system. The PID controller is quite simply configured to work with a specific object and provides satisfactory stabilization

Table 1

Values of the integral control quality criterion

T, s	$I_{25\%}$	$I_{50\%}$	$I_{75\%}$
0.3	0.0585	0.0417	0.0512
0.6	0.05791	0.03534	0.05035
0.9	0.03327	0.02319	0.02627
1.2	0.04324	0.02799	0.02373
1.5	0.0463	0.0323	0.0293
1.8	0.0487	0.0342	0.0366
2.1	0.05229	0.0379	0.04442
2.4	0.05852	0.04375	0.0471
2.7	0.0596	0.0467	0.0495
3	0.06295	0.05279	0.054

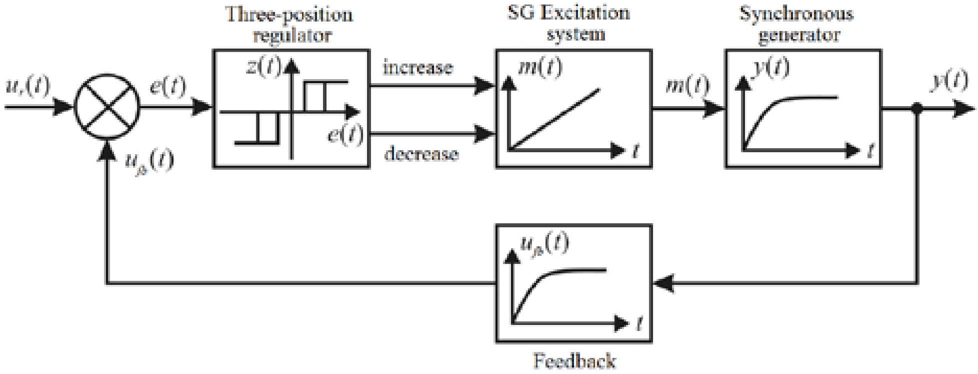


Fig. 6. The block diagram of the three-position excitation control system of the generator

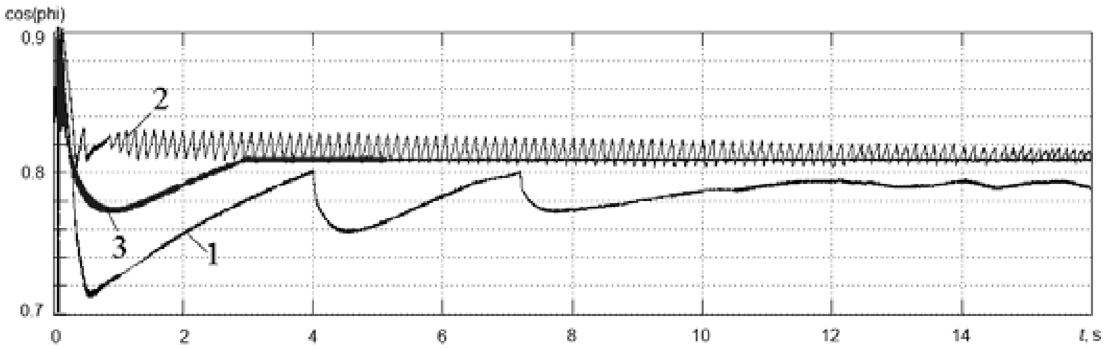


Fig. 7. Oscillograms of cosφ changes for different controllers:
1 – three-position controller; 2 – PID-controller; 3 – Fuzzy-logic based controller

of the controlled parameter with minor changes from the specified value. But with sudden changes in the operating mode of the controlled object or transition to another operating mode, the quality of the transient process in a system with a PID controller may become unsatisfactory. Figure 7 shows oscillograms of changes in the power factor of the SG, which are the result of a model study of the operation of various types of regulators for controlling the power factor of a synchronous generator during parallel operation with the network.

The simulation results demonstrated that the most effective types of controllers are fuzzy logic-based controller and a PID-controller with optimal parameter values, ensuring the fastest transient process along with the smallest cosφ deviation from the reference value.

The use of a power factor control system suggested in this paper, as well as the method of active power distribution between generators considered in [26, p. 371], allows to increase the energy efficiency of autonomous and ship electric power systems in parallel modes of operation with the network.

Conclusions. The research examined a method for controlling the excitation of a synchronous generator, in which by changing the voltage supplied to the excitation winding of the synchronous generator, stabilization of its power factor is ensured in parallel operation with the network. To effectively control the power factor of a synchronous generator, ensuring the preservation of the asymptotic (dynamic) stability of the power system, it is necessary to consider nonlinear models of power facilities and carry out the synthesis and design of control systems using methods that fully take into account the phenomena of interconnectedness and nonlinearity of processes in power facilities. In the absence of complete information about control objects, as well as information about the parameters of nonlinear models of power units, the problem under consideration can be solved using fuzzy logic. Effective structures of generator power factor controllers and a Matlab model of AEPS have been developed to study the quality of operation of different controllers. For the first time, the structure of a power factor controller using fuzzy logic has been developed to control the power factor in AEPS and SEPS. The implementation of the considered controllers based on microprocessor technology for controlling a synchronous generator will improve the energy efficiency of AEPS and SEPS by reducing the flow of reactive power between generators when they operate in parallel with the network.

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Ушкаренко О.О. СИНТЕЗ СИСТЕМИ КЕРУВАННЯ КОЕФІЦІЄНТОМ ПОТУЖНОСТІ ДЛЯ ПАРАЛЕЛЬНОЇ РОБОТИ СИНХРОННОГО ГЕНЕРАТОРА З МЕРЕЖЕЮ

У статті виконується синтез регулятора на основі нечіткої логіки для стабілізації коефіцієнта потужності синхронного генератора, що працює паралельно з мережею, шляхом керування збудженням генератора. Для досягнення мети дослідження використано метод синтезу графоаналітичної форми представлення процедури перетворення інформаційних аргументів функціональними структурами об'єктів систем керування як частин автономних електроенергетичних систем. Це дозволило сформувати математичну модель системи управління коефіцієнтом потужності та провести її аналіз за допомогою багаторівневої декомпозиції для отримання всієї необхідної інформації про основні властивості її елементів з позицій загального системного підходу. У свою чергу, аналіз процесів перетворення сигналів на різних рівнях декомпозиції в системі керування дав змогу вивчити її структурні властивості та зробити висновок про оптимальність її структури. При проектуванні системи управління були використані методи теорії нечіткої логіки, що дозволило повною мірою врахувати явище взаємопов'язаності та нелінійності процесів в автономних електроенергетичних системах. Розроблено модель автономної електроенергетичної системи та отримано результати моделювання роботи синтезованого регулятора коефіцієнту потужності. На основі проведеного моделювання виконано порівняльний аналіз якості регулювання коефіцієнта потужності за допомогою трьох типів регуляторів – нечіткого регулятора, трипозиційного регулятора та ПІД-регулятора. Встановлено, що найкращі показники якості регулювання забезпечує регулятор на основі нечіткої логіки. Використання запропонованої системи керування дає змогу підвищити енергоефективність електроенергетичної системи за рахунок реалізації такої стратегії керування, за якої синхронні генератори працюють в режимах, наближених до оптимальних.

Ключові слова: *коефіцієнт потужності, синхронний генератор, система керування, нечітка логіка, моделювання.*