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AN INNOVATIVE WAY TO CREATE SECONDARY POWER SOURCES WITH HIGH ENERGY PERFORMANCE

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AN INNOVATIVE WAY TO CREATE SECONDARY POWER SOURCES WITH HIGH ENERGY PERFORMANCE

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Abstract. *The article suggests an innovative way of creating a secondary power supply source-parametric stabilizer on the basis of magnetic semiconductor and electro-ferro-magnetic circuits with practically ideal current stabilization. In contrast to the existing methods of creating parametric stabilizers, the proposed method uses a combination of magnetic semiconductor converter and ferro-resonance-stabilizing device. This combination allows you to create a controlled parametric current stabilizer, characterized by high stability, speed and reliability in operation. Also, as a result of the analysis of the parametric current stabilizer, new analytical expressions have been obtained, allowing revealing simple and accurate methods of calculation of such devices.*

Keywords. *innovative method, secondary power supply, parametric stabilizer, magnetic semiconductor converter, ferro resonance-stabilizer, controlled parametric current stabilizer, new analytical expressions, calculation methods.*

In the development of automatic control and regulation systems are widely used secondary power supply sources (SPSS), in particular, parametric stabilizers (PS) voltage and current [1,3,9].

Therefore, the questions of theory, development and research of high-performance stabilizing devices, analysis of their work, identification of simple and accurate methods of their calculation remain relevant tasks of theoretical electrical engineering [3,8,10].

Stations built on a combination of magnetic semiconductor (MS) and electroferro-magnetic (EFM) circuits are widely used in electrical engineering and automation. Practical application of these PS is promoted by presence at them such advantages, as high reliability and efficiency in operation, absence of wearing out parts, practically unlimited service life, insensitivity to vibrations and changes of temperature of environment, simplicity of a design [1,2].

The article suggests a new way of creating a substation on the basis of a combination of magnetic semiconductor converter (MSC) and ferroresonance-stabilizing device (FSD) with practically ideal current stabilization due to the frequency control of static characteristics of the stabilizer [6].

The MSC converts the DC voltage of the power supply (PS) into an alternating voltage with an increased frequency, and at the FSD stabilizes the current value. At the same time, qualitative indicators of the FSD significantly depend on the frequency of alternating voltage. Therefore, successful functioning of the FSD depends on the operation of the MSC components, the functional converter (FC) and the voltage inverter (VI) [3,7].

Unlike well-known methods of construction of MSC, FC and IV, built on a combination of magnetic semiconductor amplifiers (MSA) is characterized by high reliability, stability and speed. FC controls the operation of VI, modulating the DC voltage of PS into AC voltage by frequency and amplitude. Since the control factor of current stability at the FSD output is the frequency and amplitude of alternating voltage, then when creating controlled substations we are interested in a structure with combined frequency-pulse and amplitude-pulse modulation (FPM-APM) [2]. In this case, the average value of the stable current of the substation in the general case is a function of three parameters:

$$I_{output} = f(\mathrm{A}, t_D, T) \quad (1)$$

Where:
A - amplitude;
t_D - duration;
$T=1/f$ - period;
f - frequency.

In turn, each of these output parameters separately can be a function of the input voltage and FC parameters, i.e.

$$A=\varphi_1(U_{input}\,; P_1, P_2, \ldots, P_m)$$
$$t_D=\varphi_2(U_{input}; P_1, P_2, \ldots, P_\kappa) \quad (2)$$
$$f=\varphi_3(U_{input}; P_1, P_2, \ldots, P_i)$$

Fig.1 shows the structural diagram of combined MSA with FPM-APM, where the amplitude (A) and duration (t_D) of output pulses are constant. Here: U_{input} - input voltage of PS; APM- amplitude - pulse modulator - VI; FPM- frequency - pulse modulator - FC.

Considering (2), the average output current of the substation is generally determined by an expression:

$$I_{output}=F[A(U_{input}), f(U_{input}), P_1', P_2', \ldots P'_{n,}, P_1, P_2, \ldots P_K] \quad (3)$$

Where:

P1, P2, ..., Rk - FPM and APM circuit parameters;

P1', P2', ..., Pn' - parameters of FC.

On the basis of combined MSC with FPM-APM a new structural scheme of frequency-controlled substation with power supply from DC voltage source with almost ideal current stabilization is proposed (Fig.2). In the scheme, the VI converts the DC voltage of the PS into an alternating voltage of rectangular shape with variable duration of t_D pulses and frequency f, controlled by the FC. Thus change of frequency f of variable voltage of rectangular form, concerning input voltage has inverse dependence:

$$f = K / U_{input} \quad (4)$$

As follows from (4), in the optimal mode of operation of the substation between the input voltage of the PS and the frequency of the FC should be a certain ratio, expressed through a coefficient of proportionality (K). Violation of this ratio affects the static characteristics of the substation, since the voltage or current stabilization mode is achieved on the ferroresonance circuit (FCr) of the stabilizing device (SD).

Where:

FCr - ferroresonance circuit; L_1 - AC load; F - harmonic filter; R - rectifier; L_2 - DC load.

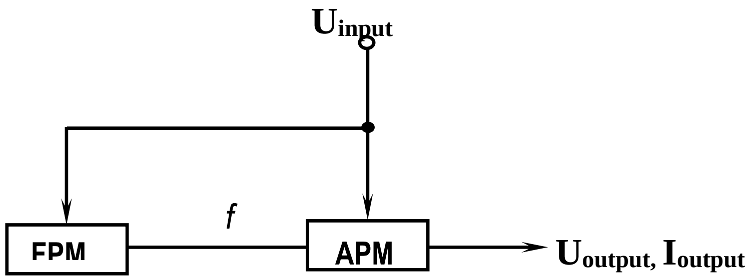

Fig. 1. The structural diagram of the combined FPM-APM converter.

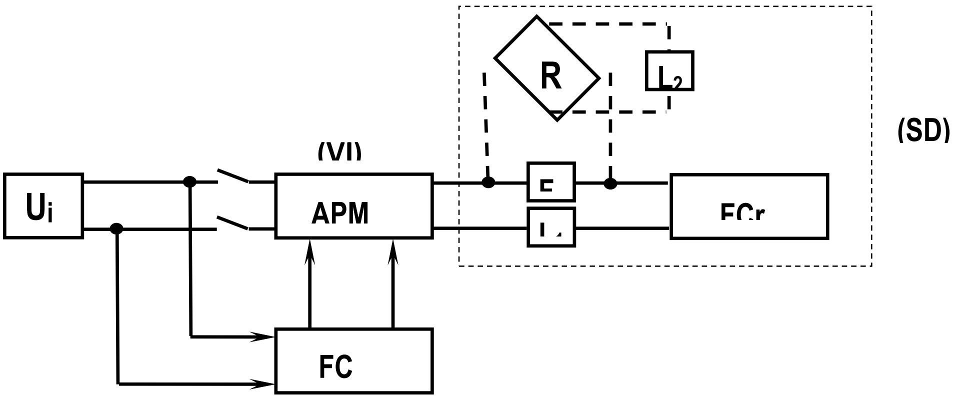

Fig. 2. Structural diagram of substation with power supply from DC voltage source.

In [5] through the graph-analytical method of building the static characteristics of the "input-output" substation, the optimal law of change in the frequency of the FC when changing the value of the input voltage of the PS to maintain a stable current is revealed.

$$K = U_{in} * f_{ФП} \quad (5)$$

The characteristics built in this way determine the law of FC frequency regulation in case of PS voltage deviation, but does not allow maintaining a stable value of load current when the load itself changes. In this connection, it is of interest to determine the law of FC frequency regulation when the load value changes.

Initial for construction of static characteristics "input-output" substation is the Volt-Amperial Characteristic (VAC) of sequential FCr, which is a known N image characteristic (Fig.3) built at two values of frequency FC 50 [Hz] and 400 [Hz].

To determine the law of change in the frequency of the substation from the input voltage we will draw three vertical lines corresponding to the load current (In = 0.5 [A]; In = 0.55 [A]; In = 0.6 [A]). As a result, we obtain six specific points (m,n,k and M,N,K), which respectively are located at different levels N of the image characteristic with a frequency of FP 50 [Hz] and 400 [Hz]. Having located the points m,n,k at frequency FP 400 [Hz], and the points M,N,K at frequency FP 50 [Hz], let us define the law of change of input voltage value from frequency substation ($f_{ФП}$ =F(U_{input}), which is a hyperbolic function and is also defined by expression (5). Thus each ideally stable value of a current of loading corresponds to its factor of proportionality K which is defined by expression:

$$K_1=U_{in}*f_{ФП1};\ K_2=U_{in}*f_{ФП2};\ K_3=U_{in}*f_{ФП3}; \qquad K_n = U_{in}* f_{ФПn} \quad (6)$$

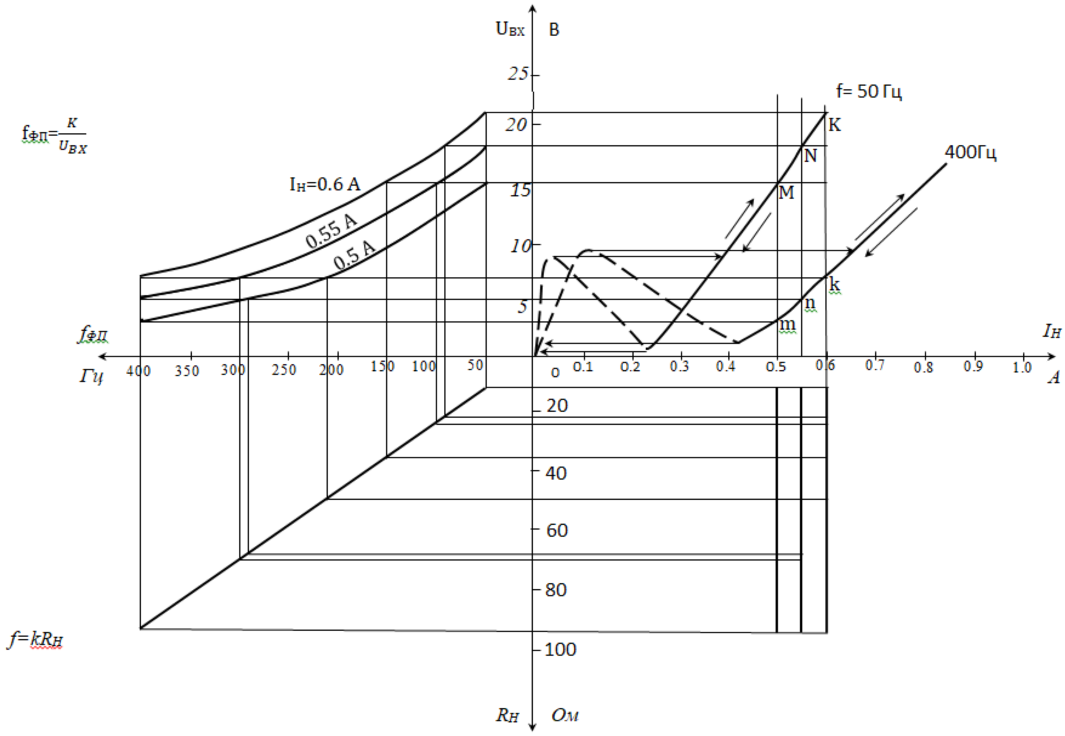

Fig.3. Grapho-analytical method of building static characteristics
Substation with almost perfect load current stabilization.

Having VAC expressing the dependence $f_{ФП} = F(U_{in})$, we can construct the external characteristic $I_н = F(R_н)$. The external characteristic of substation turns out strictly rigid, i.e. with change of size of loading $R_н$, the current of loading ($I_н$=0,5 [A]; $I_н$=0,55 [A]; $I_н$=0,6 [A]) practically remains invariable. At the same time, by changing the frequency of the FC, it is possible to adjust the value of the load current, i.e. it is possible to obtain a continuously adjustable substation with almost ideal load current stabilization [4,6].

The final characteristic representing the law of change of frequency of FC depending on value of loading $f_{ФП} = F(R_н)$ is received by linear function and frequency of FC is defined by the following expression:

$$f_{ФП} = K_* R_н \quad (7)$$

Thus, it can be seen from the graph-analytical method that the substation is practically an ideal SD, with the fluctuation of the input voltage from its nominal value or the change in the value of the load is compensated by changes in the frequency of the FC. As a result of theoretical research, the analytical expression of the law of change of the FC frequency, supporting stable current values at the deviation of input and output parameters of the substation from its nominal values, was obtained.

$$f_{фп} = \frac{1}{2\omega CSA}\left(I_{ср} - \frac{(B_r - B_0 - H_C)l_\alpha}{\omega\pi\mu_э}\right) \quad (8)$$

At constancy of static parameters of the device elements given in expression (8), the output frequency of the FC in a sufficiently wide range changes inversely proportional to the value of the PS voltage.

The average value of stable current over a half-period of the FC conversion frequency is determined from the expression

$$I_{\text{cp}} = f\omega SCA + \frac{l\alpha}{\omega\pi}\left(\frac{B_r - B_0}{\mu_э} - H_C\right) \qquad (9)$$

Where $A = B_{1m}\,\omega\cos\varphi_1 + 3B_{3m}\omega\cos\varphi_3 + 5B_{5m}\omega\cos\varphi_5$

It can be seen from expression (9) that the FC frequency is the control factor of the range and the level of stabilizing the substation current.

Thus, the main results of theoretical and practical research to create a substation with virtually ideal current stabilization can be reduced to the following conclusions:

1. An innovative structural scheme for the creation of SPSS-regulated substation on the basis of EFMC with practically ideal current stabilization is proposed.
2. A new graph-analytical method of constructing and analyzing the static characteristics of substation, where the laws of changing the frequency of the FC depending on the voltage fluctuation of the PS and the load resistance are determined, and also the ways of regulation of the range and level of stable value of current are shown.
3. New analytical expressions allowing to increase accuracy of methods of calculation and analysis of substation are received.
4. The substation is distinguished by its high energy performance: stabilization coefficient k_s=80-90%, sensitivity to FC conversion frequency σ_f=1,2-1,5%, efficiency coefficient η=0.8÷ 0.9.

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