MAIN ELECTRICAL MACHINE OF A BRUSHLESS ASYNCHRONIZED GENERATOR OF A MODEL DIESEL POWER PLANT

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Introduction. In diesel power plants (DPP), brushless synchronous generators are used. DEUs have a significant drawback - the inconstancy of the shaft speed. Electronic speed controller ensures that the shaft speed is maintained with an accuracy of < ±0.25%. However, they do not eliminate the complexity of the parallel operation of DPP generators with each other and with the network. The use of brushless asynchronized generators (BASG) in DPPs is relevant, which can provide a given frequency and phase of the voltage generator when the shaft rotation speed changes [1]. When developing BASG, the characteristics of the main electric machine (MEM), the electromachine-valve converter (EMVC), the automatic excitation regulation system (AER) are taken into account. It is important to build a model DPP based on BASG, which will be used to study various types of EMVC and AER systems.

The goal of the work: analysis of the characteristics of the MEM BASG mock-up diesel power plant with a capacity of 30 kW at different sizes of the MEM air gap, justification of the value of the nominal sliding of the MEM, development of recommendations for choosing the type of the BASG electric machine-valve converter.

Substitution scheme, equations of voltages and currents, vector diagram of the MEM when changing the slip. The MEM replacement scheme is shown in Figure 1 [2].

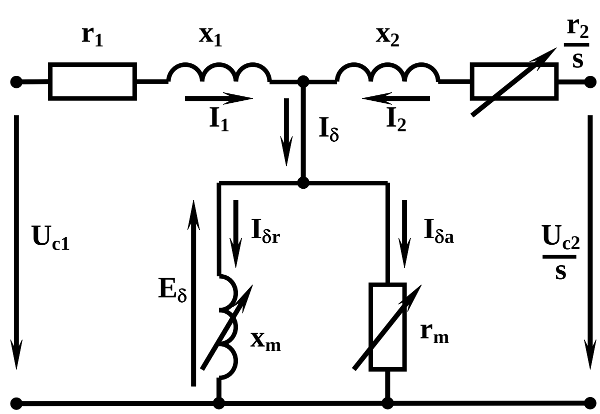

Figure 1 – Scheme of replacing the main electric machine

The figure shows: : r_1, x_1, r_2, x_2 - active resistances and dispersion resistances of MEM windings; U_{1C}, I_1 – primary network voltage and stator current; U_{2C}, I_2 – secondary network voltage and rotor current; E_δ – the resulting emf of the air gap; x_m, r_m - inductive and active resistance of the magnetizing circuit; I $I_{\delta a}$, $I_{\delta r}$, I_δ – active and reactive components and the resulting current of the magnetizing circuit. The parameters of the rotor are reduced to the stator.

The equation of voltages and magnetizing forces:

$$\begin{cases} \dot{U}_{1C} + \dot{E}_\delta - j\dot{I}_1 x_1 - \dot{I}_1 r_1 = 0 \\ \dfrac{\dot{U}_{2C}}{s} + \dot{E}_\delta - j\dot{I}_2 x_2 - \dot{I}_2 \dfrac{r_2}{s} = 0 \\ \dot{I}_1 + \dot{I}_2 = \dot{I}_\delta \end{cases} \tag{1}$$

Let's build a vector diagram of MEM voltages and currents (Fig. 2) with the specified load parameters: U_{1C}; I_1; $\cos\varphi_1$ (reactive power supplied to the power grid); r_n, x_n – load resistance. The parameters of the substitution scheme (r_1, x_1, r_2, x_2), the magnetization curve are known. Let us determine the values of U_{2C}, I_2, $\cos\varphi_2$ depending on the slip s.

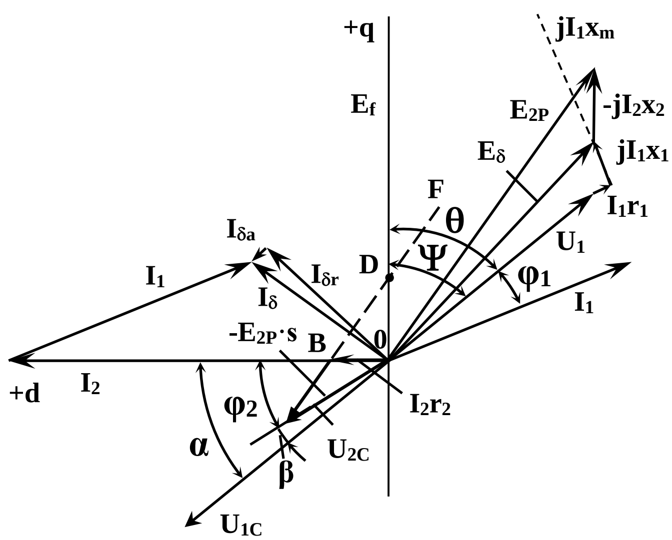

Figure 2 – Vector diagram of MEM when the amount of slip changes

by (1) (1) $\dot{E}_\delta = \dot{U}_1 + \dot{I}_1 r_1 + j\dot{I}_1 x_1$, where $\dot{U}_1 = -\dot{U}_{1C}$.

We determine the current I_δ. from the magnetization curve. Next we define

$$x_m = \frac{E_\delta}{I_{\delta\ \delta}}, \ \psi = \mathrm{atn}\frac{x_m + x_1 + x_n}{r_1 + r_n}.$$

In the axes "d" and "q" at an angle ψ, we lay down the current vector I_1.. We draw the vectors U_{1C}, U_1, E_δ, I_δ, I_2.

The resulting emf of the rotor $\dot{E}_{2P} = \dot{E}_{\delta} - j\dot{I}_2 x_2$.

EMVC load voltage $\dot{U}_{2C} = \dot{I}_2 r_2 - \dot{E}_{2P} \cdot s$.

When sliding changes, the end of the U2C vector moves along the AF line drawn through the end of the " $I_2 \cdot r_2$" vector (point B) parallel to the E_{2P} vector.

In fig. 2 shows: α is the angle between the voltage vector U_{1C} and the current vector I_2; β is the angle between the stress vectors U_{1C} and U_{2C}; θ is the MEM load angle.

Characteristics of BASG electric machine-valve converters. We present the results of calculations of the load characteristics of the EMVC BASG diesel power plant with a capacity of 30 kW (DPP-30) at different values of the MEM air gap. MEM parameters: U_N = 400 V; p = 2, $\cos\varphi_N$ = 0.85.

Table 1 shows the saturation coefficient kμ, the ratio of the EMF of the stator winding to the nominal voltage k_E, the parameters of the substitution scheme x_m, x_1 i, x_2, the current densities of the stator windings j_1 and rotor j_2, the total losses in steel p_{Fe} and copper p_{el},, the efficiency factor η and MEM load angle θ at different values of the air gap δ.

Table 1 – Calculated MEM values when $P_1 = P_{1N}$, $U = U_N$, $\cos\varphi = \cos\varphi_N$, $n_N = n_C$ and different values of δ

δ mm	k_μ	k_E	x_m r.u.	x_1 r.u.	x_2 r.u.	j_1 A/mm^2	j_2 A/mm^2	p_{Fe} W	p_{el} W	η %	θ^0
0.9	**1.443**	**1.053**	**1.952**	**0.054**	**0.144**	**4.22**	**4.18**	**814.4**	**2100**	**89.1**	**39.1**
1.2	**1.341**	**1.051**	**1.619**	**0.508**	**0.137**	**4.22**	**4.44**	**773**	**2244**	**88.8**	**36.4**
1.5	**1.279**	**1.049**	**1.386**	**0.049**	**0.133**	**4.22**	**4.71**	**747.3**	**2401**	**88.3**	**34.1**
1.8	**1.237**	**1.048**	**1.212**	**0.047**	**0.13**	**4.22**	**4.98**	**729.6**	**2571**	**87.9**	**32**

Figure 3 shows the EMVC load characteristics depending on sliding at δ = 0.9 mm (a - c) and δ = 1.8 mm (d - f):

a, d) angles φ2 and β at MEM loads $P_1 = P_{1N}$ (solid line) and $P_1 = 0.01 \cdot P_{1N}$ (dotted line); P_1

b, e) load voltage U_{2C} at MEM loads $P_1 = P_{1N}$ (solid line) and $P_1 = 0.01 \cdot P_{1N}$ (dotted line);

c, f) active, reactive and full power (P_2, Q_2, S_2) at nominal MEM load.

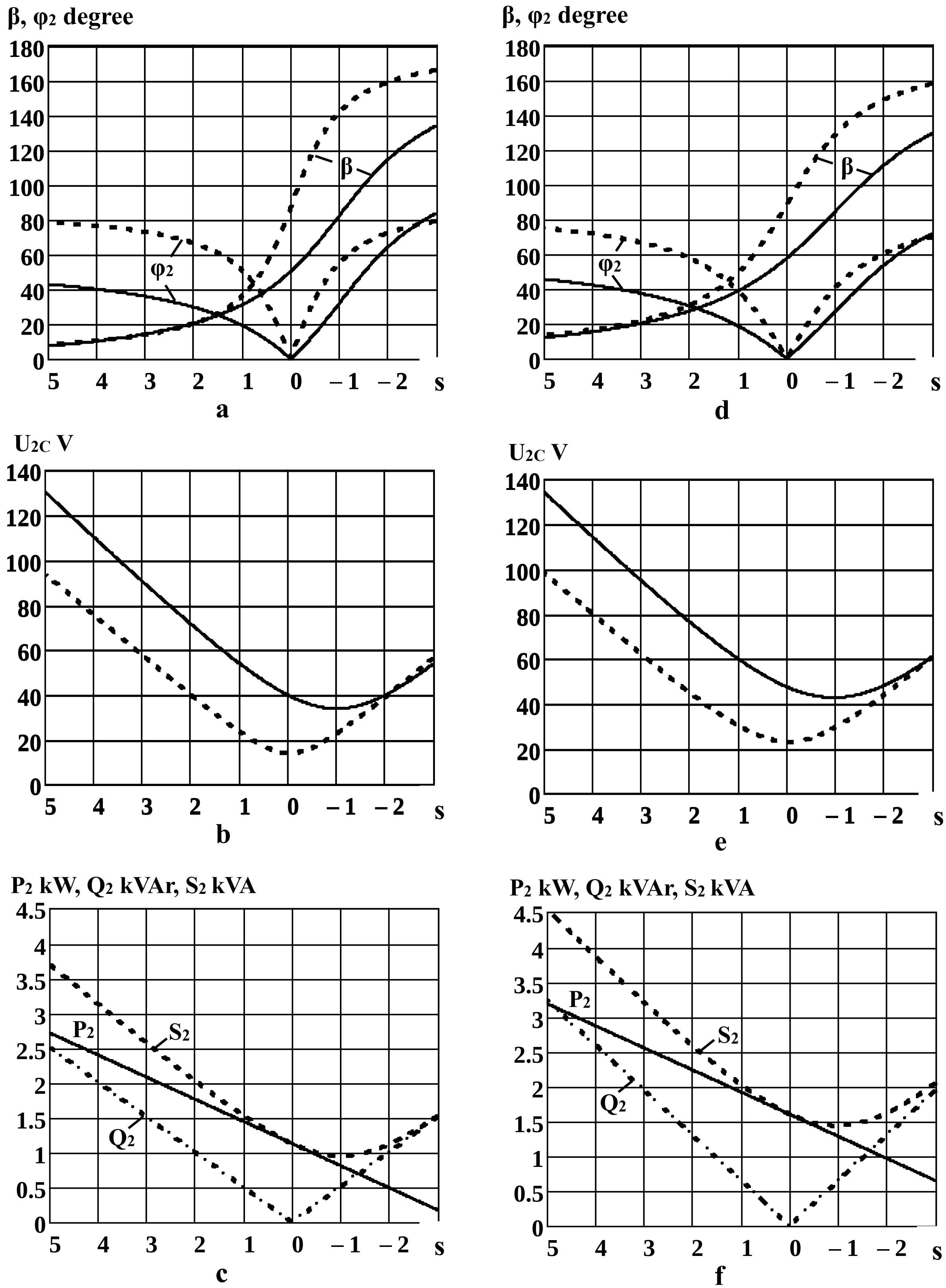

Figure 3 – Load characteristics of the frequency converter depending on the slip

According to the table 1, when the MEM air gap is increased from δ = 0.9 mm to δ = 1.8 mm, it leads to a decrease in the efficiency factor at the nominal load of the MEM by 1.2%. At the same time, the load angle θ decreases by 7.1^0 (to the value $\theta = 32^0$). Note: the selection of the MEM air gap is agreed with the machine-building plant that manufactures the DPP.

As follows from fig. 3a and fig. 3d, at different sizes of the MEM air gap, the dependence of the angles φ_2 and β on sliding is almost the same. The value of the voltage U_{2C}, the power of the secondary circuit (Fig. 3 b, c, e, f) and the weight and size characteristics of the EMVC significantly depend on the amount of slip of the MEM. The specified values significantly affect the choice of the type of EMVC, the method of controlling the frequency converter on the rotating part.

One of the main requirements for EMVC is the ability to work in the infra-low frequency range. Such requirements are met by cascade EMVCs based on direct frequency converters with modulated input voltage [2]. In cascade EMVCs, when the slip value changes, the voltage value is regulated by the control angle of the thyristors, and the load voltage phase is adjusted by the voltage on the stators of the auxiliary electric machines. Cascade EMVCs have slightly reduced weight and size indicators [2]. Work is being carried out to improve known [2, 3] and develop new types of EMVC that are capable of operating at low load frequencies, including the value s = 0.

Conclusions:

1. In the BASG of a diesel power plant, it is recommended to use a cascade EMVC based on a direct frequency converter with a modulated input voltage, which provides the required value and phase of the load voltage on the excitation windings of the MEM when sliding $s \geq 0$.

2. The recommended sliding value of MEM DPP-30 $s_N = 0.01 \div 0.02$.

3. Experimental studies of DEU-30 are recommended to be carried out with verification of the performance of various types of EMVC.

References

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