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The calculation algorithm of the magnetoelectric induction generator with the change of the magnetic flux direction (II)

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Abstract

The calculating mathematical apparatus of the magnetoelectric induction generator with change of the magnetic flux direction has been designed. The algorithm, calculating mathematical expressions, the main characteristics and principals of choosing the working points are presented.

Keywords: induction, generator, voltage, autonomous, permanent magnet, winding, characteristic, working point.

Аннотация

Разработан расчетный математический аппарат, представлен алгоритм расчета, математические выражения, основные характеристики и принципы определения рабочих точек с изменением направления магнитного потока магнитнитоэлектрического индукционного генератора.

Ключевые слова: индукция, генератор, напряжение, автономный, постоянный магнит, обмотка, характеристика, рабочая точка.

Problem settings and method justification

For designing the calculation algorithm of MIG system corresponding literature was used [1-4].

The following permissions were made for this MIG system:

- the material of the magnetic wire is not saturated,
- the losses conditioned by the storm flux are not taken into account,
- the material of the PM is homogeneous, is magnisized in corresponding field with corresponding axis until its saturated, and stabilization is done,
- the presence of short circuit in IW is excluded.

For the calculation fo the MIG the following main data was accepted as initial:

- the brand of the PM,
- length of the PM, ℓ_{PM} ,
- width of the PM, a_{PM} ,
- thickness of the PM, b_{PM} ,
- value of the voltage amplitude of the load, U_{ℓ} ,
- resistance of the load, R_{ℓ} ,
- the length of the IW's window, ℓ_{IW} ,
- the height of the IW's window, h_{IW} .

The progress of the calculation

1. Using the directory the following parameters of the PM are registered:

- the coerced force, H_c ,
- the residual induction, B_r ,
- the maximum value of the magnetic energy, $(HB)_m$.

2. The convexity coefficient of the PM material is determined

$$\vartheta_b = \frac{(BH)_m}{H_c \cdot B_r}. \quad (1)$$

3. The B(-H) characteristics of the PM is built on the coordinate axis plane according to the following expression (Fig. 7)

$$B_i = B_r \frac{H_c - H_i}{H_c - \vartheta_b H_i}, \quad (2)$$

where H_i values are in range from 0 to H_c .

4. The $W(B)$ characteristic of the PM's useful magnetic energy is constructed according to the following expression (Fig. 7)

$$W = \frac{B_i H_i}{2}, \quad (3)$$

where the values of B_i are in the range of 0 ... B_r , but the values of H_i values are determined by B(-H) curve corresponding to the value of B_i .

5. On the PM's B(-H) characteristic from the values of H_c and B_r perpendicular lines are taken and 0' point of the intersection is marked. Then points 0 and 0' are connected, A_m is the intersection of this line and the characteristics B(-H), and characterizes the maximum value of the PM's magnetic energy.

Fig. 1 shows the graphical connection between A_m and $W(B)$.

6. The m_f penetration coefficient of PM's form is determined.

The m_f penetration of PM's form, (being parallelepiped) having rectangular cross section, is determined in the following way

$$m_f = 1,7 \frac{\left(1 + \frac{a_{PM}}{b_{PM}}\right)^2 \cdot \ell_{PM}}{\frac{a_{PM}}{b_{PM}} \cdot P_{PM}} \left(1,5 + \frac{\ell_{PM}}{P_{PM}}\right), \quad (4)$$

where $P_{PM} = 2(a_{PM} + b_{PM})$.

7. Separately determining the parameters of the PM. A ray under α_1 angle is taken from the point 0 until it intersects B(-H) in the point $A_1(H_1, B_1)$, the coordinates of which characterize the working parameters of the PM.

The value of α_1 angle is determined by the following expression

$$\alpha_1 = \arctg \mu_0 \frac{m_f}{k_m}, \quad (5)$$

where k_m is the scale coefficient of the built description (Fig. 1).

8. The return line of the PM's description is built, that's why the return line coefficient is determined

$$\rho_r = \frac{B_r}{H_c} (1 - \vartheta_b). \quad (6)$$

The return line is drawn from the point A_1 under β angle, the value of which is determined as follows (Fig. 1)

$$\beta = \arctg \frac{\rho_r}{K_m}. \quad (7)$$

9. The coordinates of PM's working point A_2 are determined, which corresponds to the intersection point of the return line and B axis, $H_2=0$, B_2 .

10. PM's magnetic resistance is determined

$$R_{PM} = \frac{\ell_{PM}}{\rho_r \cdot S_{PM}}, \quad (8)$$

where $S_{PM} = a_{PM} b_{PM}$.

11. PM's H_{fc} fake coercive force is determined

$$H_{fc} = \frac{B_2}{\rho_r}. \quad (9)$$

12. PM's fake F_{f1} value of MMF is determined

$$F_{f1} = H_{fc} \cdot \ell_{PM}. \quad (10)$$

13. The value of the magnetic flux in the anchor is determined

$$\Phi_1 = \frac{F_{f1}}{R_{PM}}. \quad (11)$$

14. The value of the magnetic flux generating EMF in the IW is determined

$$\Phi_w = \Phi_1 + \Phi_2 = 2\Phi. \quad (12)$$

15. Approximate value of the EMF in the IW is determined

$$e_{IW}=kU_{\ell}=(1+\Delta_{ss})U_{\ell}, \quad (13)$$

where k is a coefficient which measures the dispersing fluxes and the decline amount of the voltage on the inner resistance of the IW, $k=1, 1/2$, Δ_{ss} is the size of a step.

16. The number of the IW's spirals

$$w = \frac{e_{iw} \cdot \Delta t}{\Phi_w} \sin \gamma, \quad (14)$$

where γ is the angle between anchor's magnetic flux and IW's spirals.

17. The d_w diameter of IW's copper wire is determined

$$d'_w \leq \sqrt{\frac{4 \cdot k_f \cdot h_{IW} \cdot \ell_{IW}}{\pi \cdot \omega}}, \quad (15)$$

where k_f is the filling coefficient of the IW.

Using corresponding literature the value of d_w is standardized and the values of S_w surface of the wire and Δ_{is} width of the isolating layer are recorded according to the type of the wire.

18. Active resistance of the IW is determined

$$r_{IW} = \rho_t \frac{\ell_{av} \cdot w}{S_w}, \quad (16)$$

where ℓ_{av} is the length of IW's average spiral, $\ell_{av}=2(a_f + b_f + 2h_{IW})$, a_f and b_f the cross-sectional dimensions of IW's frame.

19. The value of the current in the IW-load chain is determined

$$I_c = \frac{e_{iw}}{r_{IW} + R_{\ell}}. \quad (17)$$

20. The following condition is checked

$$\varepsilon \leq \frac{I_c - I_{\ell}}{I_{\ell}}, \quad (18)$$

where I_{ℓ} is the current passing through the load $I_{\ell}=U_{\ell}/R_{\ell}$, ε is the relative deviation.

If the condition (18) is not true, the value of k must be changed.

21. The placement condition of the spirals in the IW's window is checked

$$S = \ell_{IW} \cdot h_{IW} \geq \frac{\pi(d_w + \Delta_{iz})^2 w}{4k_f}, \quad (19)$$

where k_f is the filling coefficient of the IW according to d_w .

If the condition (19) is not true, the values of k or d_w must be changed.

22. The calculating power of the load is determined

$$P_{cl} = I_c^2 \cdot R_{\ell}. \quad (20)$$

23. The energy conversion efficiency (ECE) of the MIG is determined

$$\eta = \frac{R_{\ell}}{r_{IW} + R_{\ell}}. \quad (21)$$

The results of the research

For the calculation for the MIG the following main data was accepted as initial: the brand of the PM ЮН14ДК24, $H_c=48 \cdot 10^3 A/m$, $B_r=1,2T$, $(BH)_m=36 \cdot 10^3 J/m^3$, $\ell_{PM}=22mm$, $a_{PM}=11mm$, $b_{PM}=23mm$, $U_{\ell}=4V$, $R_{\ell}=20\Omega$, $\ell_{IW}=22mm$, $h_{IW}=8mm$, $\gamma=85^\circ$, the sample values had the following values $\Delta_{ss}=0,1$, $\varepsilon=0,1$:

The results of calculation: $e_{IW}=7,2V$, $w=216$, $d_w=0,63mm$, $r_{IW}=0,97\Omega$, $I_{cl}=2,42A$, $\eta=67\%$, $P_{cl}=11,7Watt$.

Conclusion

The calculating mathematical apparatus and the analysis of the structure, working principals, and magnetic system of the MIG with change of the magnetic flux direction enable development of MIG's structure by changing the brand of PM's material, the diameter of IW's wire, and the number of the spirals. It is applicable in educational, engineering, scientific and research processes.

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