ARMATURE'S REACTION IN SYNCHRONOUS DEVICES WITH SMOOTH MAGNETIC GAP

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Abstract – *the paperwork illustrates a synchronous generator with permanent magnets where the winding is mounted directly on the interior side of the no slotted armature, which simplifies the design technology for this type of generator. It is proved that the armature's reaction is six times reduced, approximately, the toothing harmonics are removed and the external feature is a lot more rigid as compared to the classical generator.*

Keywords – *magnets, armature, winding, magnetic displacement, harmonics, magnetic gap*

One of the promising directions in the development of building issues of electro-mechanical converters seems to be the more and more frequent implementation of permanent magnets in the design of synchronous devices, as well as direct current appliances.

It is acknowledged that the value of the magnetic displacement in the magnetic gap is limited by the value of the magnetic displacement in the toothing area and in the segments of the armature's and the rotor's yokes, respectively.

Reduction of magnetic displacement in these areas of the magnetic circuit determines an increase in the geometrical sizes and active weight of the electrical device.

Keeping the utilization of active material for a power unit at optimal levels is possible if the magnetic displacement in the yokes' and toothing area corresponds to the adequate saturation level of the minimum magnetic loss on these circuit segments.

In case of modern electro-mechanical converters, the technical literature [1, 2] recommends the limits of the magnetic displacement in yokes' and toothing areas to be appropriate to the magnetic displacement in the armature- this value does not exceed 1 adze.

It is important to see that in order to increase the power corresponding to one unity of active weight of electro-technical steel it is necessary to increase the value of magnetic displacement in the yoke. Yet, this is impossible to achieve at the same sizes of the active part because it would increase the magnetic leakage and reduce the yield.

Consequently, one of the main difficulties in this context is related to the saturation level of the electro-technical steel from the armature and toothing areas.

The utilization of the permanent magnets opens the way to a new solution of this issue, as the toothing area of the armature is removed.

Lately the technology of manufacturing permanent magnets has caused the increase of the remanent flux density with 20 -30 %. Nowadays permanent magnets with magnetic displacement of 1, 2 – 1,3 T.

The implementation of these magnets in the design of the no toothing alternator devices would ensure the value of the magnetic displacement under one T corresponding to the magnetic displacement in the yoke of classical alternator devices for a ten times bigger yoke.

The paperwork illustrates the design of rotating or fixed coil permanent magnets, no toothing armature (Fig. 1).

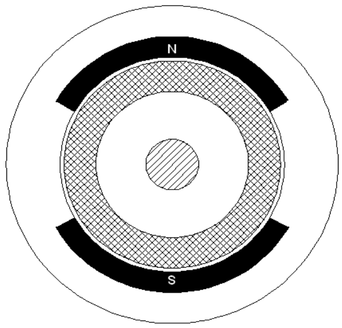

Fig. 1 - Alternator device with permanent magnets with no toothing on the yoke fixed coil armature: 1 – statoric yoke, 2- winding, 3 - magnets, 4- rotor, 5- shaft

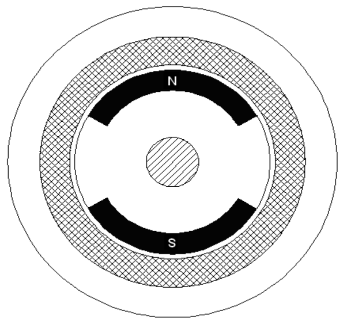

Fig. 2 - Alternator device with permanent magnets with no toothing on the yoke- rotor: 1 – Statoric yoke, 2- winding, 3- magnets, 4- rotor, 5- shaft

In Fig 1 a design on the interior side of the armature the three phased winding is mounted, while in fig 2 design the alternator device with the winding mounted on the rotor is presented. In both cases the magnetic gap has increased because the toothing of the armature is missing.

In this context the advantages of the converters illustrated in the paperwork are obvious:

- the manufacturing technology of the armature has been simplified due to removal of the blanking out procedure;
- the winding of the armature is mounted in the space previously occupied by the toothing;
- the winding's layer of the armature is twice reduced as compared to the winding mounted on the toothing;
- the reaction of the armature is significantly reduced, its action can sometimes be neglected;
- the toothing harmonics and the correspondent torques are removed;
- the viability of the device is improved, the noise and vibrations are reduced.

With the help of the finite element method in the study of an alternator with permanent magnets with toothing (Fig. 3), the diagram of the magnetic displacement in the magnetic gap has been obtained (Fig. 5).

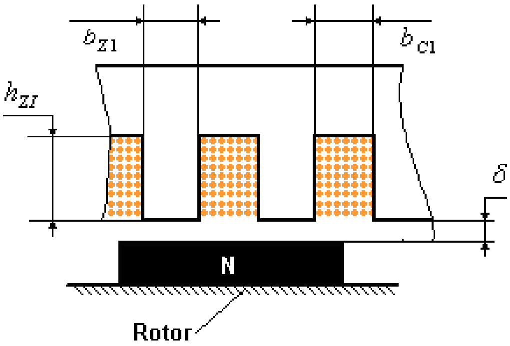

Fig. 3 - Alternator with permanent magnets developed in plane section toothing armature;

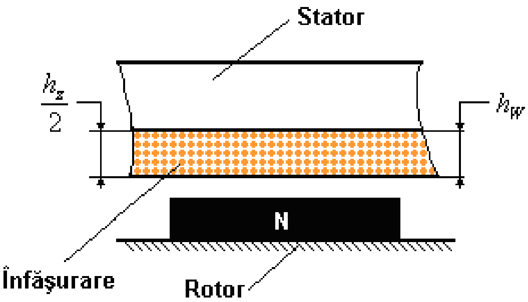

Fig. 4 - Alternator with permanent magnets developed in plane section no toothing armature

In this case the instantaneous value of the magnetizing force produced by the armature's currents for the three-phased alternator with the toothing armature is given with:

$$f_\nu = \frac{m_1\sqrt{2}}{\pi}\frac{w_1 \cdot k_{w\nu}}{\nu \cdot \ p} I_I \sin(\omega t - \frac{\pi}{\tau \nu} x) \qquad (1)$$

While the magnetic displacement

$$b_\nu = \frac{\mu_0}{2\delta \cdot k_\delta k_\mu} f_\nu = \frac{\mu_0}{2\delta \cdot k_\delta k_\mu}\frac{m_1\sqrt{2}}{\pi}\frac{w_1 \cdot k_{w\nu}}{\nu \cdot \ p} I_\nu \sin(\omega t - \frac{\pi}{\tau \nu} x) \qquad (2)$$

$$k_{w\nu} = k_{s\nu} \cdot k_{q\nu}$$

where

$$k_{s\nu} = \sin\left(\frac{\nu\pi}{2}\right) \quad \text{and} \quad k_q = \frac{\sin\left(\frac{\nu y}{2} q\right)}{q \sin\left(\frac{\nu y}{2}\right)}$$

The amplitudes of magnetizing forces and magnetic displacement for all the harmonics of ν order are written down while the presence of toothing on the armature is taken into account:

$$F_{m\nu_c} = \frac{m_1 w_1 k_{w\nu}}{\pi \nu p} I_I \qquad (3)$$

$$B_{m\nu_c} = \frac{\mu_0}{2\delta k_\delta k_\mu}\frac{w_1 k_{w\nu}}{\pi \nu p} I_I \qquad (4)$$

We assume that the magnetic system is saturated, so that odd harmonics are generated:

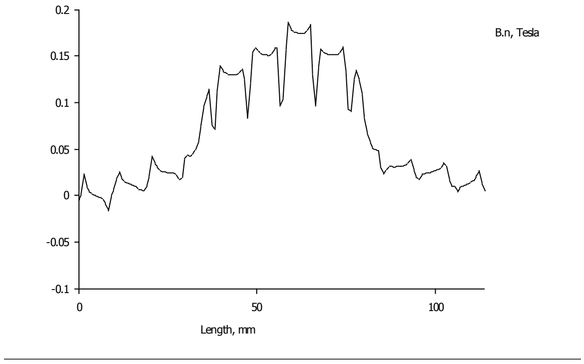

Fig. 5 - Curves of magnetic displacement on the magentic gap a generator with toothing armature

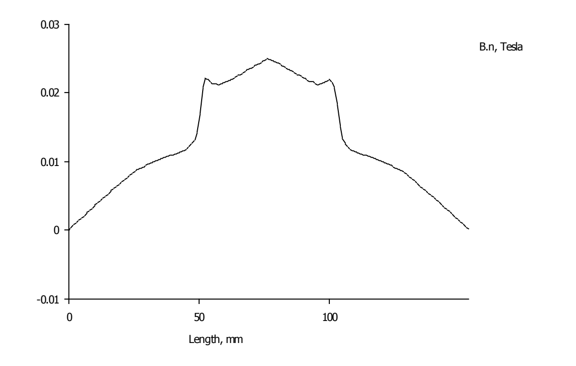

Fig. 6 - Curves of magnetic displacement on the magentic gap a generator with no toothing armature

Fig. 6 illustrates the curve of the magnetic displacement in the magnetic gap produced by the armature's currents (of reaction) in the case of an alternator generator with no toothing (Fig. 4).

In the case of the alternator device induced by the permanent magnets with no toothing the magnetic permeability of the magnets $\mu_m = \mu_0$. The armature's winding is mounted on the interior past of the fixed coil. The height of the wire layer of the winding mounted on the armature $h_{w1} = \frac{h_{z1}}{2}$ if the average width of the toothing and of the cut $b_{c1} = b_{z1}$.

On the internal part of the armature there are no cuts and the toothing harmonics disappear $k_S = 1$, while the value of the magnetic gap becomes equal to $\left(\frac{h_{z1}}{2} + \delta\right)$, then equations (3) and (4) become:

$$F_m = \frac{m_1 w_1 k_{w\nu}}{\pi p \nu} I_I \quad (5)$$

$$B_m = \frac{\mu_0 w_1 k_{w\nu}}{2\left(\frac{h_{z1}}{2} + \delta\right) \cdot \pi \nu p} I_I \quad (6)$$

6) divided to (4) results in:

$$\frac{B_{m_c}}{B_m} = \frac{\left(\frac{h_{z1}}{2} + \delta\right)}{k_\mu \delta k_\delta}$$

Consequently, for the same magnetizing force $F_m = F_{m\nu_c}$ the magnetic displacement of the armature's reaction will be reduced with approximately $\frac{\left(\frac{h_{z1}}{2} + \delta\right)}{k_\mu \delta k_\delta}$ times.

Fig. 3 presents the curves of the magnetic displacement's variations in the magnetic gap of the alternator device with toothing and no toothing armature. The reaction flux according to the oscillograms obtained is approximately 6 times lower in the case of the no toothing alternator device, as compared to the toothing alternator device.

Thus the reaction of the armature does not influence the external feature significantly enough for an alternator generator with permanent magnets.

CONCLUSIONS:

The paperwork illustrates the design of an alternator (synchronous) generator and the armature's winding. In this way the manufacturing technology of this generator is essentially simplified.

It is found that in the case of synchronous devices, mainly the synchronous generators with permanent magnets, the reaction of the armature is a lot more reduced. The external feature is rigid at the variation of the load in large limits, the toothing harmonics disappear and the curve of the magnetic displacement draws closer to the sine curve, the quality of the electrical energy increases.

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[2] T. Ambros, A. cîmpeanu, L. Iazloveţchi.*Generator sincron axial pentru microhidrocentrale*, Energetica, 2004, no.1, pp. 33-35.

Tudor Ambros was born in July 26th, 1938 in Soroca County, Romania.

He graduated the Technical University of Moldova. He is a PhD in Technical Sciences. He was head of department and dean deputy on scientific issues. He has published over 150 scientific and methodical works, three school books and two monographs in the field of modern and cosmic electro mechanics.