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FINITE ELEMENT METHOD STUDY OF THE HYBRID SYNCHRONOUS GENERATOR BY SKEWED STATOR SLOTS

BY

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Abstract. The study of the hybrid synchronous generator with skewed stator slots is performed. The skewed stator slots help to improve the line voltage wave-form and reduce the superior rank harmonics. The line voltage wave-forms obtained and the flux density for each semi-machine are presented.

Key words: hybrid synchronous generator; skewed stator slots.

1. Introduction

Taking into account the main use of the hybrid synchronous generator on automotives and its goal to increase the generated power, it was tried to improve the line voltage wave-form by skewed stator slots. Thus, with the aid of the computation software that uses the finite element method (FEM) Flux Skewed; simulations were performed on the two semi-machines on which the stator slot was 8 degrees skewed.

2. Constructive Elements of the Hybrid Synchronous Generator

The analysed hybrid synchronous generator has a construction different

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from that of a classical synchronous generator, because it is practically realized by two synchronous semi-machines, one with permanent magnet excitation used to produce the main flux and the other with electromagnetic excitation used to regulate the voltage at different loads or speeds.

The machines that form the generator have a common three-phase stator winding and separate magnetic circuits.

The negative effect of the excitation winding at the use of a reverse excitation current, which might influence the permanent magnet demagnetization, is eliminated because the two magnetic circuits are separated.

In Fig.1 it is presented a cross section through the permanent magnet semi-machine where one can observe: the rotor shaft, the stator yoke, the core ducts, the rotor lamination, the stator winding and the permanent magnets. The used permanent magnets are of Ferrite type having a remanent induction, B_r = = 0.41 T and a coercive field, H_c = 190 kA/m.

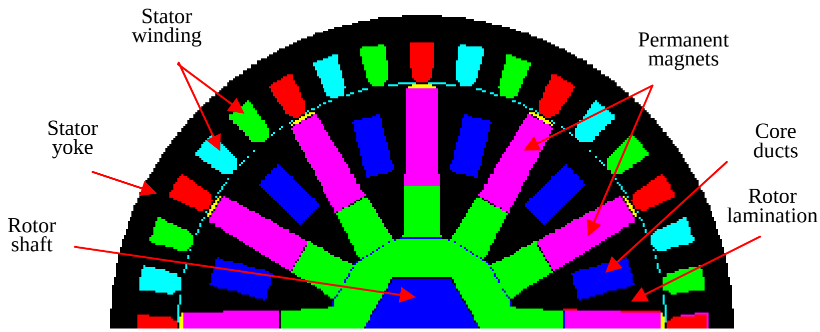

Fig. 1 – Cross section through the permanent magnet semi-machine.

In Fig. 2 it is presented a cross section through the electromagnetic excitation semi-machine and one can notice: the rotor shaft, the stator yoke, wye stator winding, the flux barriers, the rotor lamination and the excitation winding.

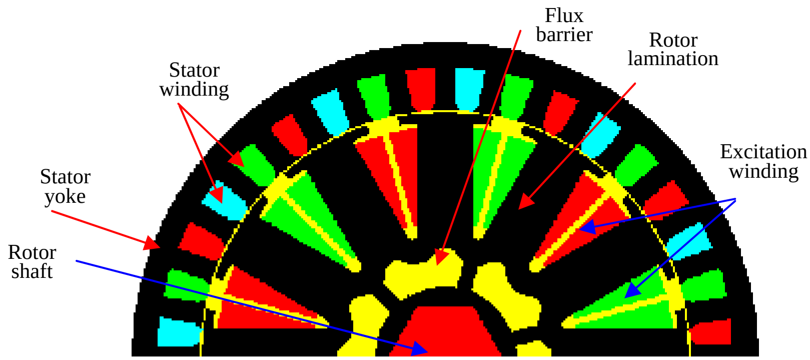

Fig. 2 – Cross section through the electromagnetic excitation semi-machine.

The common elements of the analysed synchronous generator are the stator winding and the shaft on which the two rotors are fixed.

The hybrid synchronous generator has 36 stator slots, 6 pole pairs and the three-phase stator winding which may be delta or wye connected with one slot per pole and phase. The length of the permanent magnet semi-machine is of 45 mm and that of the electromagnetic excitation is of 35 mm.

3. Simulations Using Flux Skewed Software

For simulation, the 2-D models of the two semi-machines were used, the one with electromagnetic excitation and the permanent magnet one, respectively. The two models were analysed separately and then the results were cumulated by superposing the effects. Several transient type analysis were done, at a 3,000 r.p.m. speed, at no load, the stator winding being wye connected.

For all the performed simulations the excitation current was maintained constant at a 4 A value.

4. The Analysis of the Obtained Results

A first series of solving of the introduced models offers us the possibility to visualize the magnetic induction through the two component semi-machines of the hybrid synchronous generator.

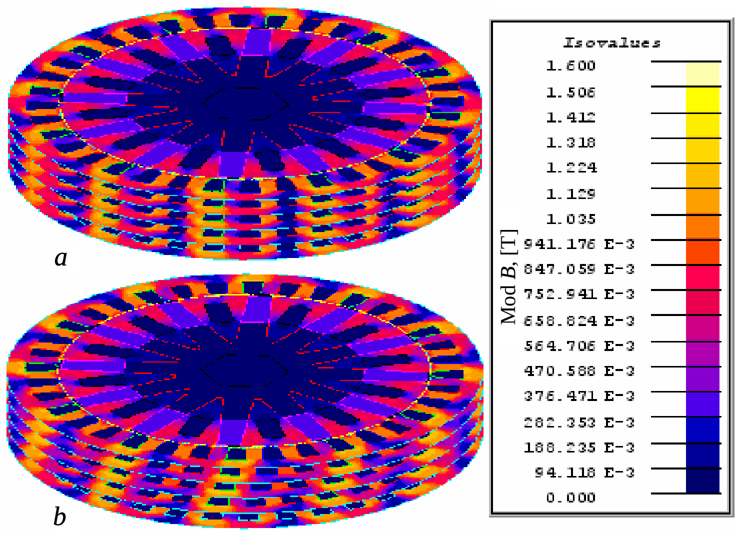

Fig. 3 – Flux density coloured map in the permanent magnet semi-machine.

Knowing the value of the magnetic induction in different constructive elements of the semi-machines is a real help provided by the simulation software, in order to establish the saturation degree of the magnetic circuit.

In Fig. 3 ***a*** it is presented the flux density coloured map for the permanent magnet semi-machine, the initial situation when the stator slots are straight, while in Fig. 3 ***b*** it is presented the flux density coloured map when the stator slots are 8 degrees skewed.

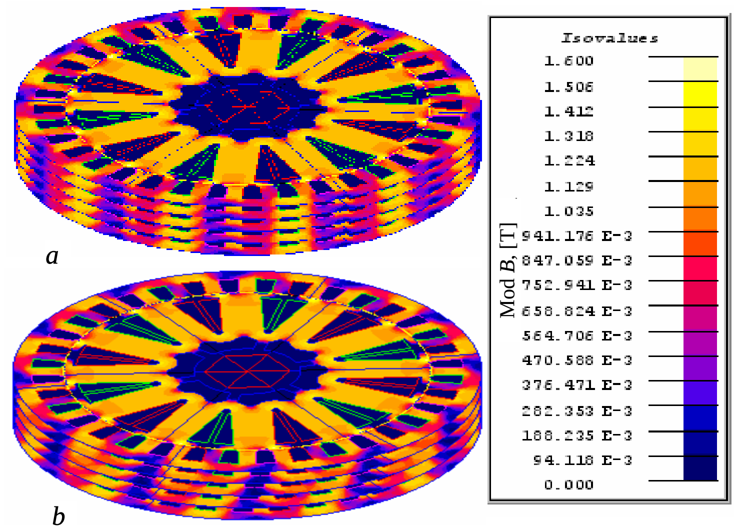

Fig. 4 – Flux density coloured map in the electromagnetic excitation semi-machine.

In Fig. 4 ***a*** one may observe the flux density coloured map foe the electro-magnetic excitation semi-machine, initial situation, while in Fig. 4 ***b*** there is presented the flux density coloured map when the stator slots are 8 degrees skewed.

In Fig.5 there is presented the line voltage and its decomposition into harmonics for the electromagnetic excitation semi-machine in the initial situation when the slots are straight.

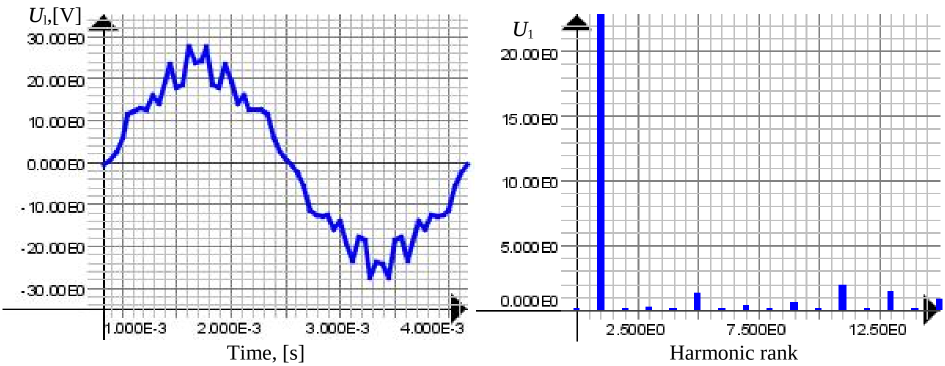

Fig. 5 – Line voltage and its decomposition into harmonics – initial situation.

In Fig. 6 there is represented the line voltage and its decomposition into harmonics for the electromagnetic excitation semi-machine, when the stator slot is 8 degrees skewed and we may observe a diminishing the rank 7, 11 and 13 harmonics. The line voltage fundamental has a value of 22.8 V and it decreases once with the stator slots skew up to the value of 22.18 V, but a wave-form closer to the sinusoidal is obtained.

In Fig. 7 there is represented the line voltage and its decomposition into harmonics when the stator slots are straight and the value of the fundamental is 32.13 V. In Fig. 8 there is represented the line voltage and its decomposition into harmonics when the stator slots are 8 degrees skewed.

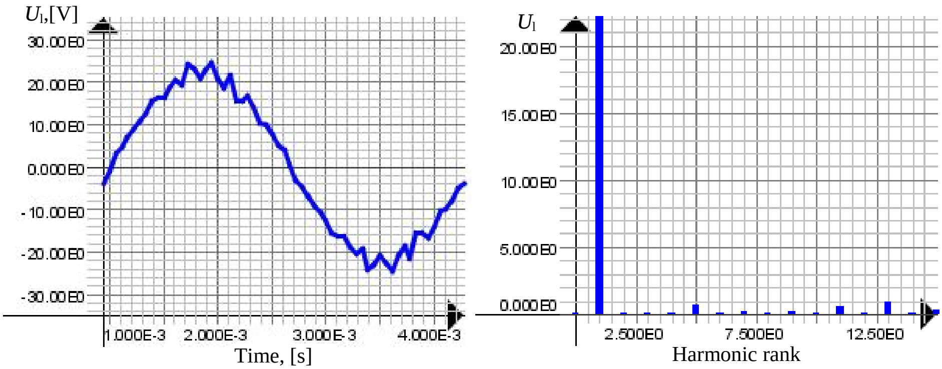

Fig. 6 – Line voltage and its decomposition into harmonics when the slot is 8 degrees.

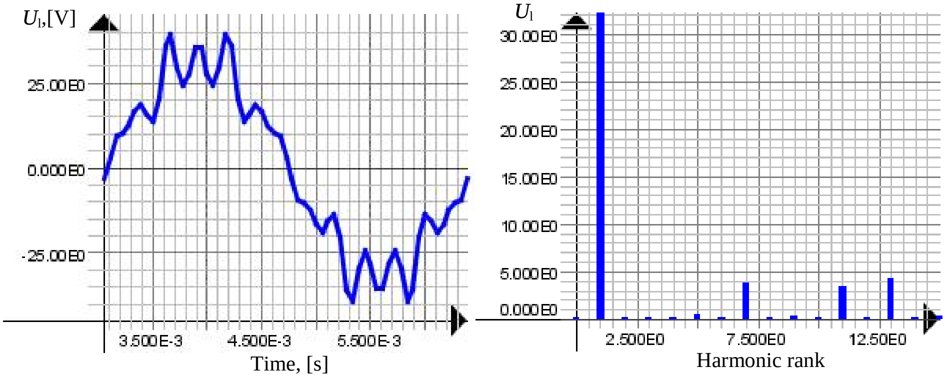

Fig. 7 – Line voltage and its decomposition into harmonics – initial situation.

The value of the fundamental decreases once with the slots skew to a value of 31.31 V, but a line voltage wave form closer to the sinusoidal is obtained. At the same time one may observe the diminishing of rank 7, 11 and 13 harmonics.

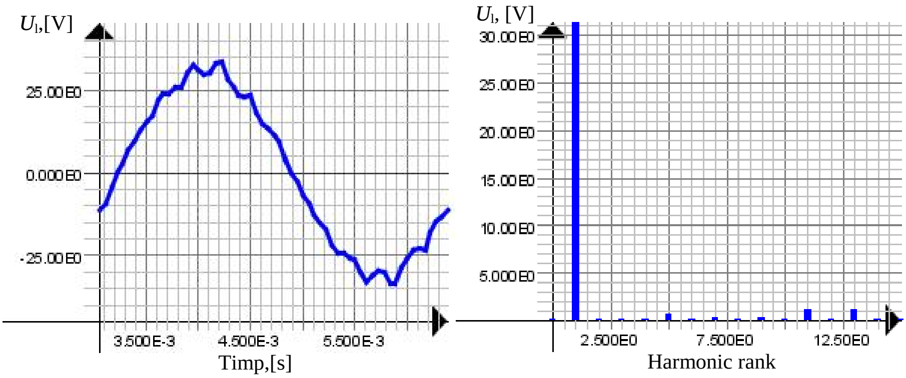

Fig. 8 – Line voltage and harmonics decomposition when the slot is 8 degrees skewed.

5. Conclusions

The stator slots skew represents an improvement solution of the line voltage wave form, together with the elimination of the superior rank harmonics.

The use of simulation programmes in achieving the field computations is a real help in predetermining the functioning characteristics.

REFERENCES

Amara Y., Lucidarme I., Gabsi M., Ahmed B.H., Akemakou D.A., *A New Topology of Hybrid Synchronous Machine*. IEEE Trans. Ind. Appl., **37**, *5*, 1273-1281 (2001).

Amara Y., Vido L., Gabsi M., Hoang E., Ahmed A., Lécrivain M., *Hybrid Excitation Synchronous Machines: Energy-Efficient Solution for Vehicles Propulsion*. IEEE Trans. on Vehic. Technol., **58**, *5*, 2137-2149 (2009).

Munteanu A., Simion Al., Livadaru L., *Comparative Study on the Under-Load Operation with Imposed Conditions of a New Hybrid Synchronous Generator*. Bul. Inst. Politehnic, Iaşi, **LI (LV)**, *5*, s. Electrot., Energ., Electron., 161-166 (2005).

STUDIUL UNUI GENERATOR SINCRON HIBRID CU CRESTĂTURI STATORICE ÎNCLINATE

(Rezumat)

Se studiază efectele produse de realizarea înclinării crestăturilor statorice la un generator sincron hibrid. Utilizarea acestei soluţii constructive ajută la îmbunătăţirea formei de undă a tensiunii de linie prin diminuarea armonicilor de rang superior.