ANALELE UNIVERSITĂŢII
"EFTIMIE MURGU" REŞIŢA
ANUL XXI, NR. 2, 2014, ISSN 1453 - 7397

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Rotor Pole Pitch Factor Influence on the Operation Parameters of a 9/10 Pole Permanent Magnet Synchronous Machine

The present paper is aimed to determine the pole pitch factor influence on the operating parameters for the considered structure. Transient analysis is used to obtain the results for each of the studied pole pitch factor. The results concern the cogging torque values, the back EMF, medium torque and torque ripple values.

Keywords: permanent magnet machines, finite element methods, rotating machine transient analysis, torque

1. Introduction

In this paper the influence of rotor pole pitch factor influence, for a nine slots ten poles permanent magnet machine is presented. The structure presented in this paper is not new [1] but each new permanent magnet machine design has to take into consideration a lot of parameters. This parameters can be: the magnet shape and emplacement, stator teeth shape, stator winding [2], slot opening [3,4], air-gap width etc. The considered values for the rotor pole pitch factor were 0.5, 0.6, 0.66, 0.7, 0.8, 0.9 and 1. For each of these values the back EMF waveform, torque ripples and medium torque obtained were considered.

The concentrated winding construction has a lot of advantages over distributed windings [5] like shorter end windings and ease of manufacture. This advantages makes them a better choice in permanent magnet synchronous design.

Even if the design algorithm can be studied [1,6] the permanent magnet material, especially the magnet volume [7] and pole pitch factor require optimization which can be achieved by the usage of finite element analysis with dedicated software.

2. No-load generator analysis

The structure studied in this paper is presented in Figure 1. As it can be seen the rotor has a dual-layer concentrated winding placed in nine slots. Each coil has 28 wires with a wire diameter of 1.25 mm. The rotor has ten rare earth permanent magnets with parallel magnetization. In the left side of the rotor the lowest pole pitch factor of 0.5 can be observed. In the right side of the rotor the unitary pole pitch factor is presented. The permanent magnet volume was maintained constant for each studied case. Also the equivalent air-gap was maintained to a constant value by burying the magnets for lower pole pitch factor values.

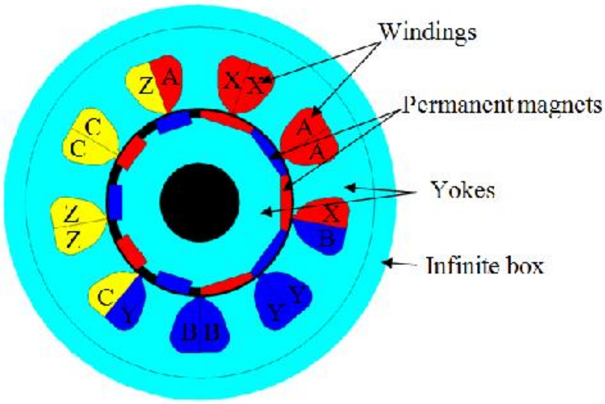

Figure 1. Permanent magnet synchronous machine geometry

The equivalent circuit used for the transient generator study is presented in Figure 2. With R_{f1}, R_{f2}, R_{f3} the end winding resistances were considered with a value of 0.3 Ω. The end winding inductances are noted with L_{f1}, L_{f2}, L_{f3} and the calculated value was 0.0016 H. With R_1 - R_3 three high value resistances are placed in order to measure the phase voltages. R_{m1} - R_{m3} are also high value resistances use to measure the line voltages. As expected the line voltages have a sinusoidal waveform for all of the considered pole pitch factors. The harmonic content over one period of the line voltages are presented in Figure 3. The fundamental value increases with the increase in rotor pole pitch factor. Also the lower order harmonic content is reduced, high order harmonics are absent.

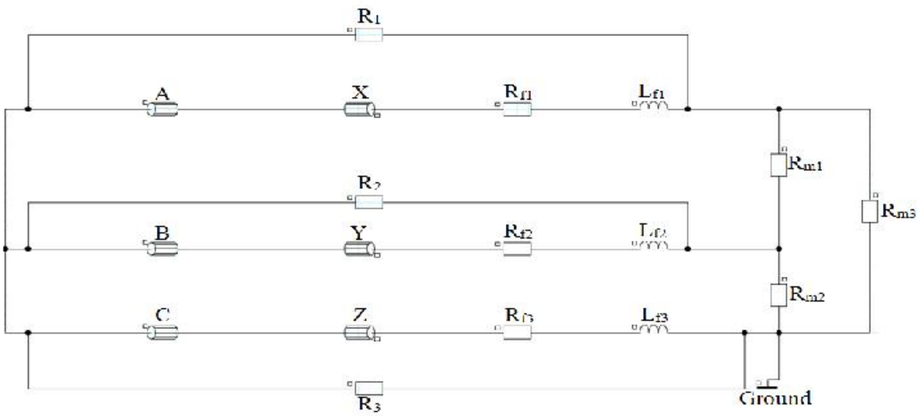

Figure 2. Equivalent circuit for the no-load generator operation

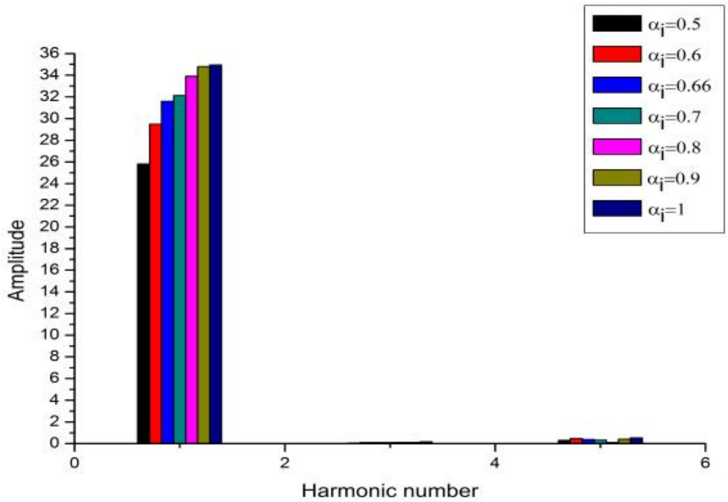

Figure 3. Back EMF harmonic content

The cogging torque rms values are presented in Figure 4, for each of the considered pole pitch factors. The cogging torque has low values for almost all of the considered constructions given the fact that the rotor is never perfectly in a perfect aligned position with the stator magnetic circuit.

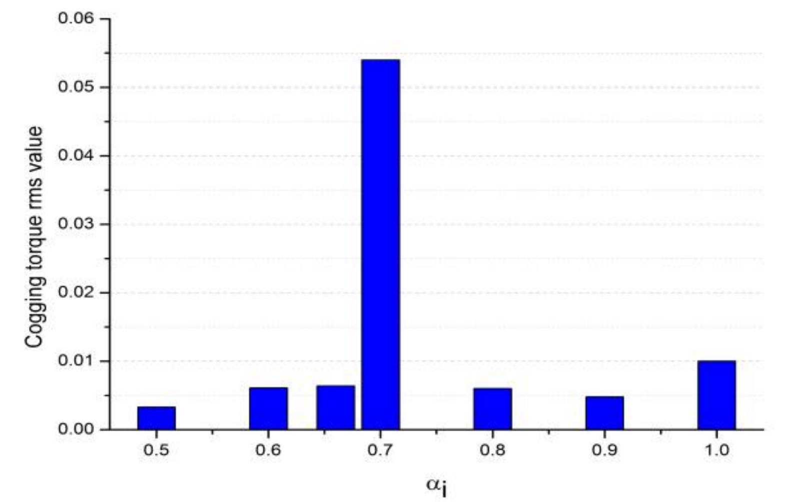

Figure 4. Cogging torque rms value for each studied rotor pole pitch factor

3. Torque ripples and medium torque

For the torque ripple transient analysis takes into consideration the equivalent circuit presented in Figure 2. For this type of study the stator circuit was maintained but three current sources are introduced (I_1, I_2, I_3) with a current value of 10 A, imposed in the design stage. With S_1 and S_2 two solid conductors are used in order to couple the electromagnetic rotor circuit with the stator one and also they can be used to determine the losses produced by eddy currents in the permanent magnets.

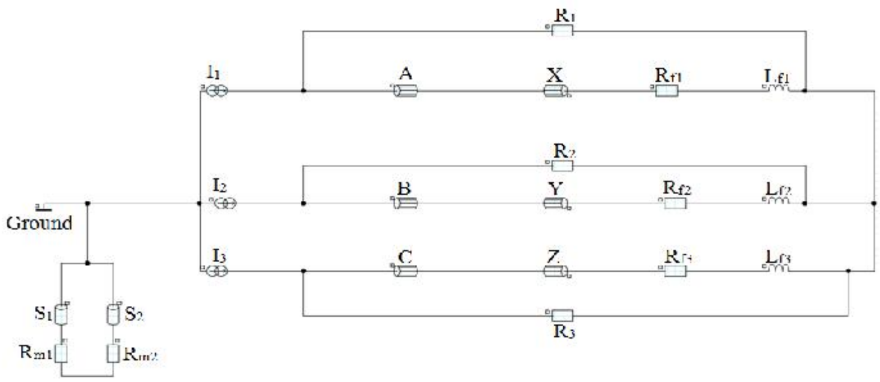

Figure 5. Equivalent circuit for torque ripple transient analysis

The medium torque obtained for each construction for the considered value of the current is presented in Figure 6. Also the torque ripples are presented on the right side. Again for higher values of the rotor pole pitch factor an increase in the obtained torque can be noticed and also a decrease in the torque ripple. The lowest value for the torque ripple is close to 0.1 Nm which corresponds to a value of approximately 5% if the medium produced torque for the rated current.

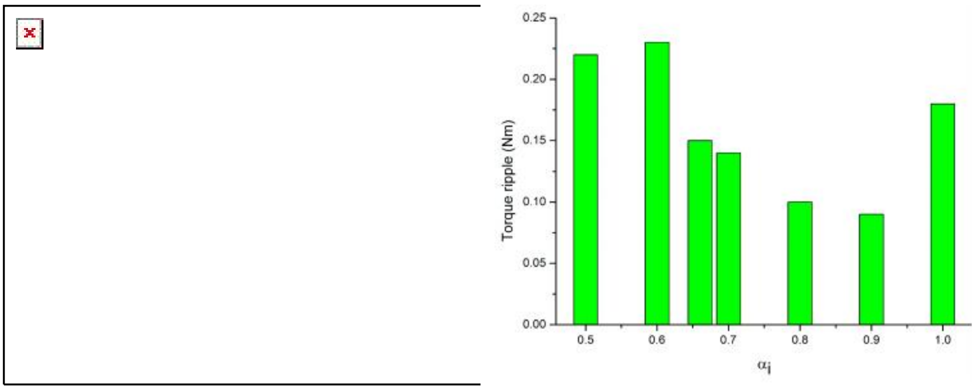

Figure 6. Medium torque obtained and torque ripple values

4. Conclusion

High values for the rotor pole pitch factor can ensure higher values for the medium torque and generated voltage, but also a decrease in torque ripples. But having a high value for the pole pitch factor also means that the permanent magnet material has to be placed on the rotor surface witch may decrease the over-all maximum operation speed due to lower mechanical strength for these constructions. This draw-back can be solved by using outer rotor cofigurations.

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