Optimization switching strategy for synchronous motor fed by current inverter using Finite Element analysis

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Abstract— In a load-commutated synchronous motor, the torque is driven by the currents in the stator windings, and these currents depend on the rotor position. Since the stator phases are wye-connected, the static torque generated by two stator phases connected in series and powered with a constant current offers sufficient information to design a suitable current control strategy. For a synchronous machine studied, of inversely construction, with fractional slot number, by magnetostatic simulation in FLUX2D, the switching sequence for the current inverter thyristors is correlated with rotor position, using the maximization of static torque as optimization criteria.

Keywords— synchronous machine, finite element, static torque, optimization

I. INTRODUCTION

In this paper a load-commutated synchronous machine model which takes the magnetic circuit configurations of machine and the realistic construction of the damper winding into account is established.

Field analysis using FLUX2D [1] allows determination of firing instants of inverter thyristors by the condition of producing a maximum average torque.

In a load-commutated synchronous motor, the torque is driven by the currents in the stator windings (rotor windings for inverse construction), and these currents depend on the rotor position. Because the electromagnetic torque is affected by the back emf and the rotor (armature) currents, it is important to have a thorough knowledge of the static torques for design a suitable current control strategy. For this reason, the static torque can be measured connecting two rotor phases in series, powered with a constant current.

II. METHOD AND RESULTS

For calculation of static torque using FLUX2D, a conventional circuit analysis method is used, to assembly the magnetic potential equations and the current and voltage equations for each conductor. Non-linear properties are taken into account using the Newton-Raphson algorithm and a conjugate gradient method is used to solve the system at each time step. To compute static torque the "moving airgap" feature of FLUX2D is used.

With a circuit structure of figure 1, by magnetostatic simulation in FLUX2D, the variation of maximized static torque shown in figure 2, for i_f = 1.52 (p.u.) and constant armature current (i = 0.81 (p.u.)), is obtained [2].

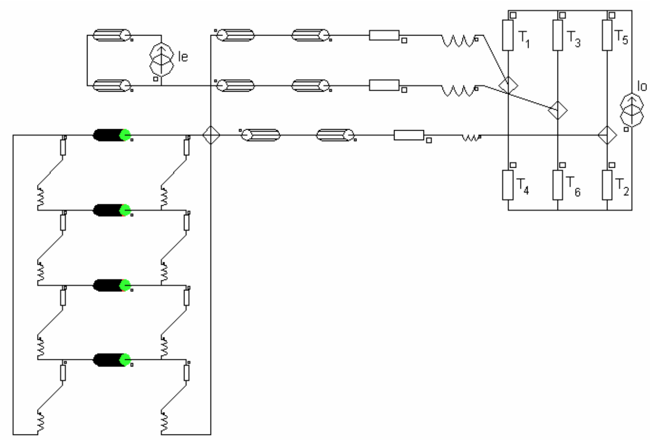

Fig. 1. Structure of complete circuit for static torque simulation.

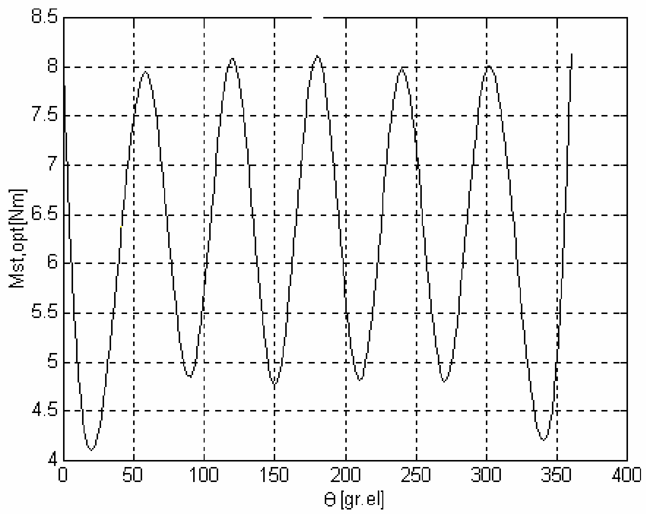

Fig. 2. Static torque maximized.

For unsymmetrical supply (two-phase, without correlation with rotor position) the flux lines shows a non-uniform distribution (figure 3). For optimized control (two-phase supply, with correlation with rotor position), the spectrum of the flux lines is much more uniform (figure 4).

Due to the fractional number of slots per pole and phase the harmonic content of emf's is very small. Consequently, the electromagnetic torque is less affected by non-linearities dues to inverter operation.

For this control optimization was investigated the cases of synchronous motor with and without damper winding; the difference between the maximum static torque for the two cases is quite small: T_{st} = 8.138 Nm - with damper cage and T_{st} = 8.0 Nm - without cage.

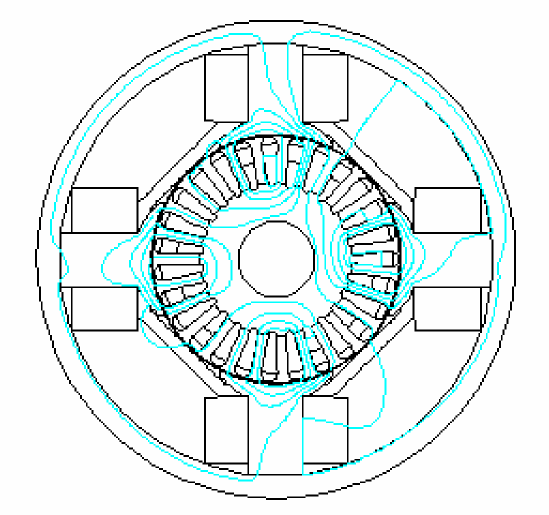

Fig. 3. Flux lines for one rotor position (certain).

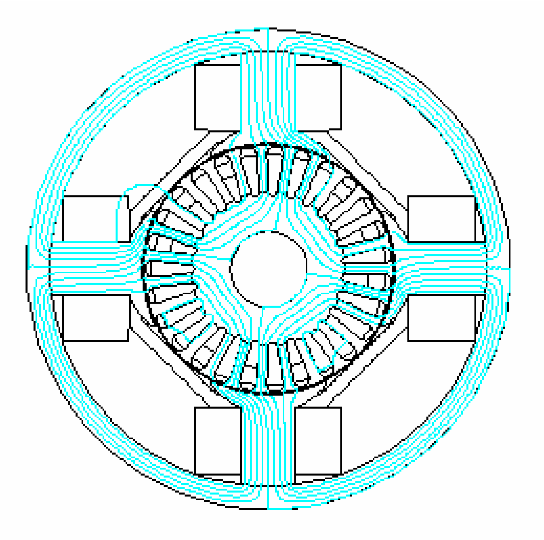

Fig. 4. Flux lines for one rotor position (optimized).

By compensating variations of current harmonics and by shielding electromagnetic effect, the damper winding acts in reduction of power factor angle, φ, thus determining a increase of overload capability of the motor.

The copper damper takes over a part of the imposed magnetomotive force and thus reduces iron losses; the reduction is most emphasized as the optimization strategy is applied.

This study, also, covered a computational method for determining the operating parameters of a synchronous machine using simulation of the Standstill Frequency Response Test (SSFR).

For these determinations, FLUX2D in linear, quasi-static and coupled with electric circuits problems, is used. The circuit structure is shown in figure 5.

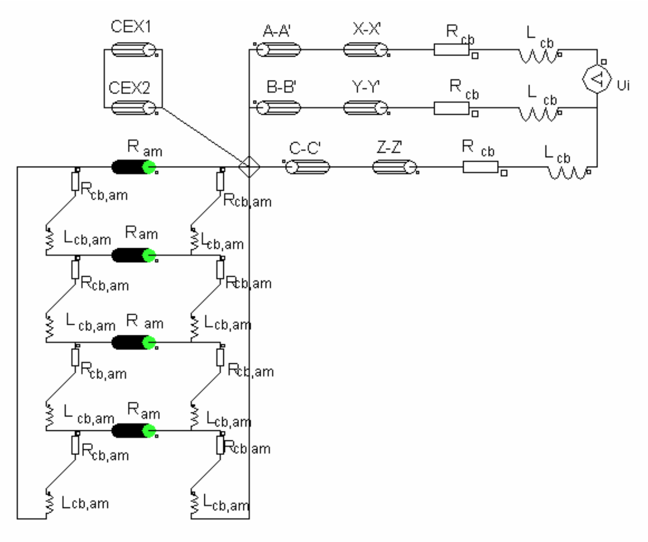

Fig. 5. Structure of complete circuit for SSFR Test simulation.

For U_i = 31mV, by simulation using FLUX2D, was obtained a synchronous inductance L_d = 34.385mH and a subtransient inductance, L''_d = 4.87mH, values with a good agreement with experimental ones (L_d = 36mH, respectively, L''_d = 5.4mH).

For an increase of U_i (U_i = 12.4V) was calculate the saturated values: $L_{d,sat}$ = 31.4mH and $L''_{d,sat} \cong L''_d$.

Also, for a configuration without damper cage, is obtained an increased value of the subtransient inductance, L''_d = 5.67mH.

Computed results of machine parameters are compared to values obtained from experimental determinations. The Finite Element analysis validates the parameters and evidentiate the need to consider the sub-subtransient reactances due to the skin effect.

III. References

[1] FLUX2D: Finite element software for electromagnetic applications; CEDRAT (CEE), MAGSOFT (USA).

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