OPTIMALIZATION OF SWITCHED RELUCTANCE MOTOR CONTROL

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ABSTRACT

This paper deals with an optimization of switch-on and switch-off SRM angels. The optimization consists of two steps. Maximum average torque angels are determined in first step. These results are used as starting points in second step that optimizes the switching angels on minimal losses in windings. The optimization algorithm uses a simplified mathematical model of one SRM phase. The phase model is created in Simulink.

1 INTRODUCTION

The switched reluctance motor is a rotating electric machine where both stator and rotor have salient poles. The stator consists of simple concentric windings. There are neither windings or bar wires on the rotor. The stator windings on the diametrically opposite poles are connected in series to form a single phase. When the stator pole pair is energized by the phase winding, the nearest rotor pole pair is attracted toward the position, where the magnetic path has a minimum reluctance. Thus, by energizing the consecutive stator phases in sequence, it is possible to develop a torque in either direction of rotation.

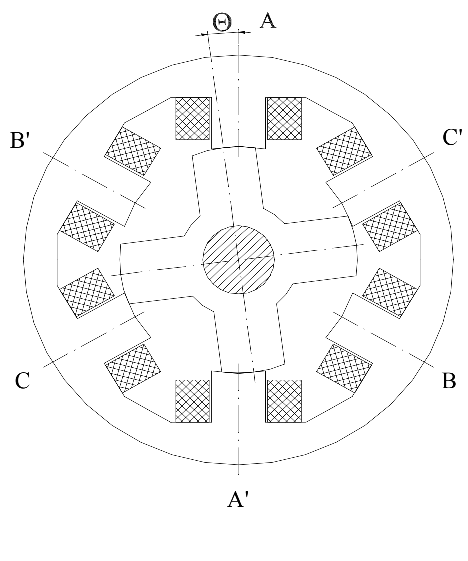

Fig. 1: *Cross-section of 3-phase SRM*

2 THE MATHEMATICAL MODEL OF SRM PHASE

A switched reluctance motor is a real non-linear system. Therefore the torque generation process can be described accurately only by a non-linear mathematical model. The chosen optimization method calls the model many times over each optimization sequence therefore isn't a complex model of whole switched reluctance motor used, but a simplified model of one phase. The model is based on the equation (1), (2) and (3).

$$\frac{\mathrm{d}\Theta}{\mathrm{d}t} = \omega \tag{1}$$

$$\frac{\mathrm{d}i_A}{\mathrm{d}t} = \frac{1}{\frac{\partial \Psi_A(i_A,\Theta)}{\partial i_A}} \left(v_A - R_{ph} \cdot i_A - \frac{\partial \Psi_A(i_A,\Theta)}{\partial \Theta} \omega \right) \tag{2}$$

$$T_A = f(i_A, \Theta_A) \tag{3}$$

Where Θ - rotor position angle, ω - angular velocity, Ψ_A - magnetic flux-linkage, i_A - phase current, R_{ph} – phase resistance, T_A - phase torque and v_A - phase voltage.

The equation (2) describes an electric part of motor and contains partial derivations of flux-linkage characteristic that is determined by finite element method. The function of phase torque versus phase current and rotor position (3) is taken from [2]. The model parameters correspond to the prototype of switched reluctance motor that is shown in fig.1.

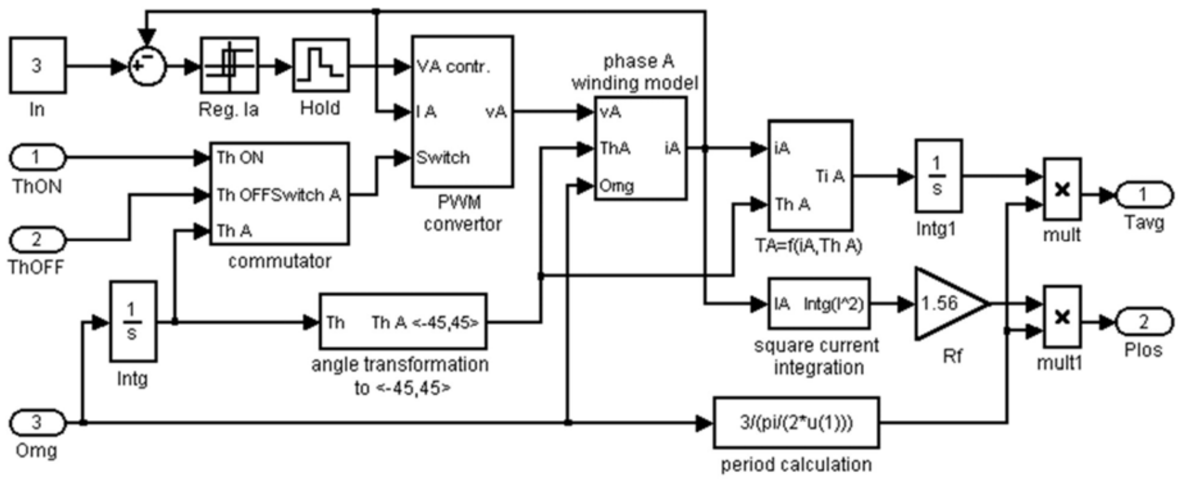

Fig. 2: *Mathematical model of SRM phase that is used for the optimization algorithm.*

The structure of used model is shown in fig.2. Input parameters are switch-on angle, switch-off angle and angular speed. The Simulink model is called by optimization algorithm that determines input parameters and duration of simulation. The model contains a current control loop with non-linear bistable regulator. The current is maintained approximately constant around the reference level, that is set to the nominal phase value $I_n = 3A$. The commutator activates the converter for an angular interval that is defined by Θ_{on}, Θ_{off} and instantaneous angle Θ. The output parameters are convert on 3-phase motor values.

3 THE OPTIMALIZATION METHOD

The optimization is performed by a response surface methodology (RSM) that is often explained by the mountain-climber analogy. Function values are counted in several points around the starting point. The algorithm steps in the direction of point with a maximal (minimal) gradient. The optimization algorithm is described by the flowchart in fig. 3.

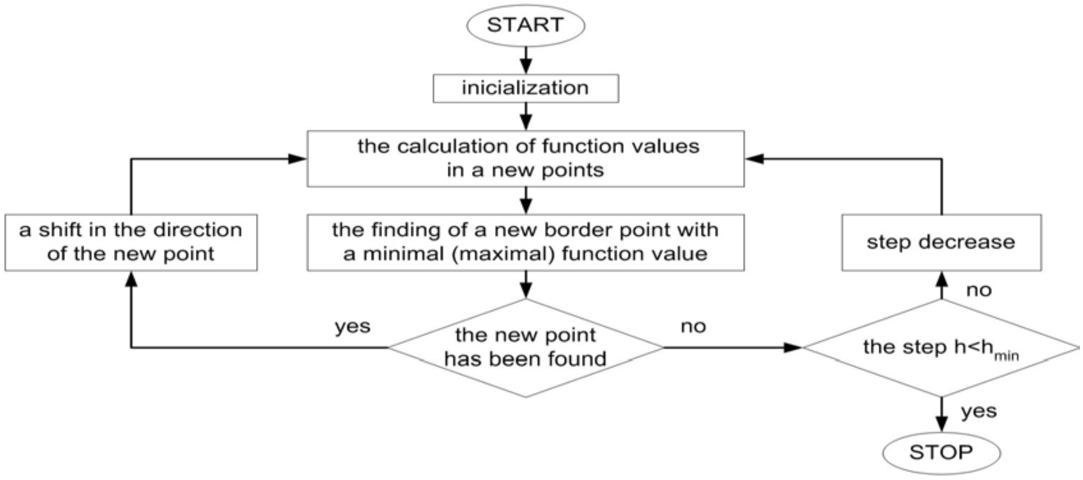

Fig. 3: *Flowchart of optimization algorithm.*

The optimization consists of two steps. The switching angels, which generate maximum average torque, are determined in first step. Average torque values versus switching angles Θ_{on} and Θ_{off} for ω = 80 rad/s are shown in fig.4. The starting point of optimization is at the position Θ_{on} = -20° and Θ_{off} = -15°. The other marks show the way that is used by the optimization algorithm to get to the operating point with a maximum average torque.

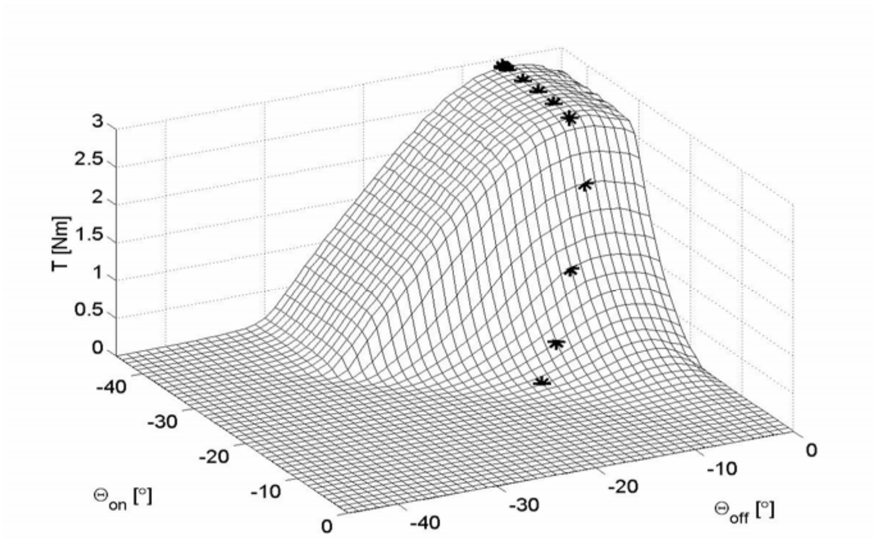

Fig. 4: *Average torque values versus switch-on angle and switch-off angle for ω = 80 rad/s. The marks show the way that is used by the optimization algorithm to get to the operating point with a maximum average torque.*

The results from the first step are used as starting points in the second step that optimizes the switching angels on minimal resistance losses in windings. The reason is that the average torque from the simulation has to be greater or equal than require average torque in all optimization step points. This condition ensures against a current pulse contraction and an average moment fall.

4 CONCLUSION

The results of control optimization on maximal efficiency are shown in fig.5. The optimal switching angles Θ_{on} and Θ_{off} for different speed and loading values, are shown. In the area where the switched reluctance motor is out of an operating range are values $\Theta_{on} = -50°$ or $\Theta_{off} = -30°$. An error appears in the area $\omega = 0 – 100$ rad/s. The reason is a mathematical model inaccuracy especially the function (3).

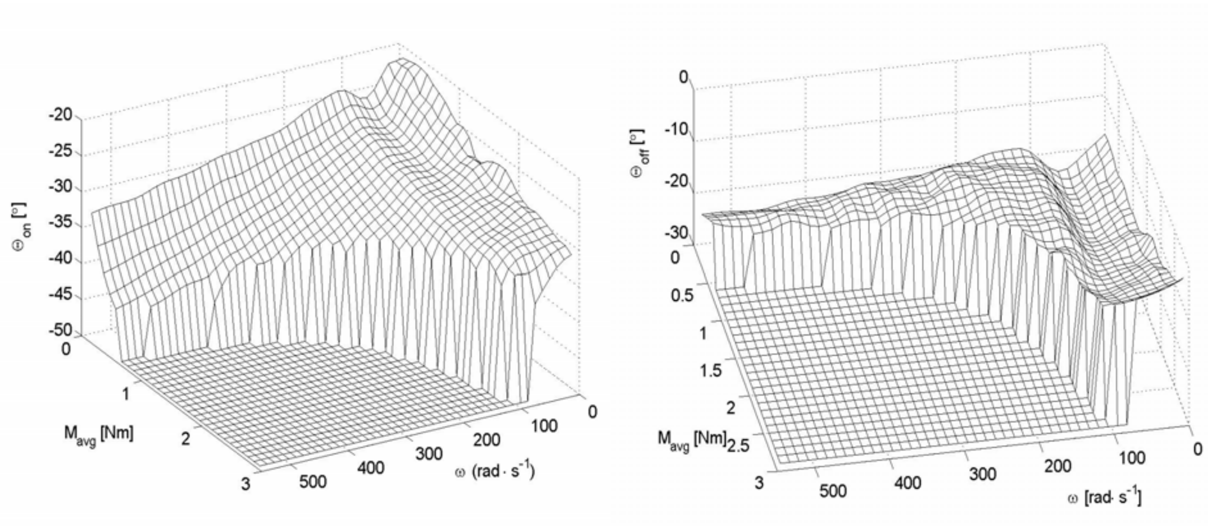

Fig. 5: *Switching angles optimized on minimum losses in windings. The values $\Theta_{on} = -50°$ and $\Theta_{off} = -30°$ indicate area, where the motor is out of its operating range.*

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