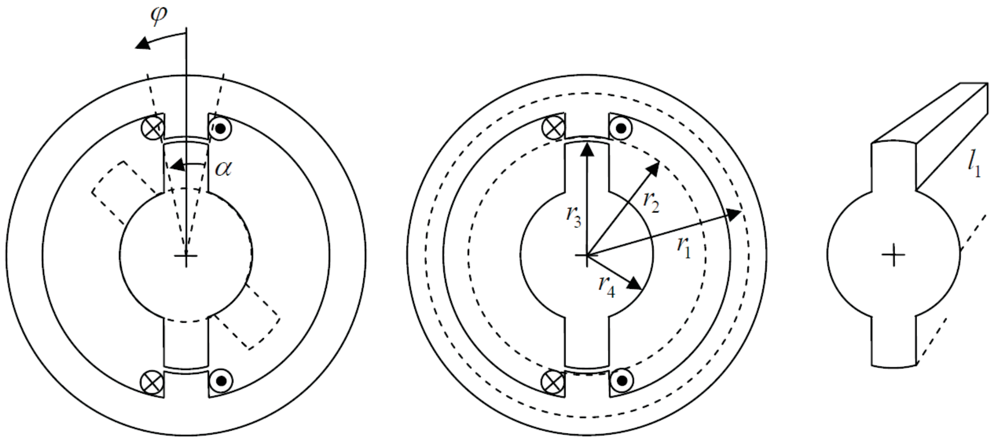
Exercise 7: Switched-Reluctance-Motor

Consider a two pole switched-reluctance motor. The SR-Motor is operated at a constant speed.



The dimensions of the motor are the following:

$r_1 = 6,75\text{cm}, r_2 = 3,6\text{cm}, r_3 = 3,57\text{cm}, r_4 = 1,40\text{cm}, \alpha = 20°, l_1 = 11,4\text{cm}$

The number of turns per pole are $N = 72$. The motor is operated below saturation, furthermore the resistance of the stator windings can be neglected. The iron of the stator can be considered as a linear material with a relative permeability, $\mu_{r,FeS} = 4000$. In addition, the magnetic resistance of the rotor can be also neglected.

Problem 1: Preperation for the MATLAB excercise

a) Set up the equation for the magnetic resistance of the apparatus with respect to angle φ. (Assume r_1 as the mean radius for the calculation of the flux path through the yoke.)

b) Sketch the inductivity profile with respect to angle φ.

c) Set up the equation of the magnetic flux $\psi(\varphi, I)$.

d) Set up the equation of the torque T.

e) Set up the derivation of the current $\dot{I}$.

f) Set up the equation for the desired current $I^*(\varphi)$. Sketch the profile of I^* in respect to the angle φ.

g) Sketch a functional diagram of the current control of the SRM.

Problem 2: MATLAB excercise

a) Using the code provided:

- Plot the profile of the inductivity $L(\varphi)$ for at least 2 periods.
- Plot the profile $\psi(I)$ for different angles φ.
- Plot the profile of the torque $T(\varphi)$ for at least 2 periods. The current has to assumed constant at I=10A. How has the motor to be excited to operate in motoring mode?

b) Using the Simulink template provided, build up the block I_w which defines $I = I(\varphi)$ in such a way, that the commanded current in motoring operation is the output of this function.

c) Using the Simulink template provided, build up the block $T(\varepsilon, i)$ which defines $T = T(I, \varphi)$ in such a way, that the actual torque is the output of this function.

d) Set up a Simulink block $I(U, \varphi)$ which defines the equation: $\dot{I} = \dot{I}(U, \omega, \varphi, I)$.

$$\dot{I} = \frac{U - RI - I\frac{\partial L(\varphi)}{\partial \varphi}\omega}{L_{\text{diff}}(\varphi)}$$

e) Set up a Simulink block $dL/dPhi$ which defines the equation both the inductance $L(\varphi)$ and its derivative $dL(\varphi)/d\varphi$ according to the equations:

$$L = \frac{(2N)^2\mu_0 b_p L_l[(\alpha - \varphi)l_1 + \varphi l_2]}{2\alpha l_1 l_2 + R_{\text{Fe}}\mu_0 b_p L_l[(\alpha - \varphi)l_1 + \varphi l_2]}$$

$$\Rightarrow \qquad \frac{\partial L}{\partial \varphi} = -\frac{2\alpha b_p (2N)^2 l_1 l_2 l_l \mu_0 (l_1 - l_2)}{[\varphi b_p (l_1 - l_2) l_l \mu_0 R_{\text{Fe}} - \alpha(b_p l_l \mu_0 R_{\text{Fe}} + 2l_2)l_1]^2}$$

f) Design a subsystem for the controller $P - Controller$. Consider uniquely a proportional gain P and voltage simulation for the DC-link set to $U_{DC,max} = 500V$.

g) Determine an acceptable P-factor of the current controller for a constant speed. ($\omega_m =$ 50rad/s, $U_{DC} = 500V$). Analyze the response of the system for different values of ω_m and gain P. Which factors should be considered when selecting P? How can the negative peak of the torque be suppressed? Why is there a steady state error for some operating points?