University of Utah

Department of Electrical & Computer Engineering

ECE 5570 **Control of Electric Motors** **Fall 2010**

Homework#5 – Due December 6, 2010

Problem 4.5:

(a) Write the equations corresponding to the slip control scheme of Fig. 4.21. Find the transfer function of the system from S to ω assuming zero friction/load torque, and the steady-state torque value for small slip. Neglecting the block limiting slip, obtain the transfer function from ω_{REF} to ω and find conditions on the proportional and integral gains so that the system has two poles at $s = -a_d$.

(b) Simulate the slip control scheme for an induction motor with parameters: $R_R = 0.201\ \Omega$, $L_S = L_R = 0.036\ H$, $M = 0.035\ H$, $J = 0.026\ kg.m^2$ and $n_p = 1$. Use an induction motor model with rotor fluxes as state variables and based in the AB (or stator) coordinate frame (*i.e.,* use the last three equations of (4.89) with $\omega_F = 0$ and the indices F, G replaced bv A, B). Let the peak stator current $I_{REF} = 60A$ and let $a_d = 1\ rad/s$. Implement the PI controller using a modified feedforward gain $k_F = 2/3$, limit the slip as in Fig 4.21 to the optimal range $|S| < 1/T_R$, and suspend integration of the error in the PI regulator when the slip limit is reached. Let the speed reference be a step command of 3600 rpm, and set the load/friction torque at zero for the first three seconds and at $20N.m$ afterwards. Simulate the system for 10 seconds and plot the speed of the motor in rpm as a function of time.

(c) Write the equations for a field-oriented control scheme obtained by modifying the slip control scheme of part a) using the adjustment of Fig. 4.26. Let i_{sd} be constant and Ψ fixed to its steady-state value ($\Psi = Mi_{sd}$). Show that the open-loop system is similar to part a) but with a different gain.

(d) Simulate the field-oriented controller in the same conditions as part b). Set the current i_{sd} such that $I_S = I_{MAX}$ when $i_{sd} = i_{sq}$ (so that the maximum torque can be obtained under the current limit). With this choice, the current limit is satisfied if $i_{sq} \leq i_{sd}$, which requires that $|S| < 1/T_R$. Therefore, the PI controller can be applied with the same limiting and anti-wind-up.

(e) Increase the parameter a_d to 10, and plot the speed responses of the slip and of the field-oriented schemes. Compare the responses to those obtained earlier. Note that the desired closed-loop pole location is further in the left-half plane than the pole of the flux system, which is at $s = -1/T_R$.

Problem 5.1:

Assume that phases B and C of a $Y-$connected brushless DC motor are tied together, and that an AC source is connected to the terminals A and B/C. Assume that the speed of the motor is zero. What are the resistance and inductance values measured using this connection as functions of the motor parameters? Compare the values to those obtained with a line-to-line measurement, and deduce which connection yields the largest L/R time constant.

Problem 6.2:

(a) Write the equations for a DQ control scheme regulating the position of a three-phase permanent synchronous motor, following Fig. 6.5. Use the vectorial DQ transformation with $i_h = 0$. The field weakening, velocity estimation, and current amplifier components may be left as "black boxes."

(b) Given measurements of the line-to-line resistance, inductance, and back-emf constant, find the DQ motor parameters R_{eq}, L_{eq}, $K_{e,eq}$, $K_{m,eq}$ of a $Y-$connected motor (this assumption is made so that the controller of part a) can be used with the line currents equal to the winding currents). Give the computation of $i_{d,REF}$ that should be used for speeds where only the voltage limit is active, and give the value of the transfer function from $i_{q,REF}$ to θ that should be taken for the design of the PI controller.