University of Utah

Department of Electrical & Computer Engineering

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

Homework#3 – Due October 1, 2010

1. Courses notes. Problem 3.1.

2. **Problem 3.2 (revised):**

   (a) Consider the model of a two-phase synchronous motor with n_p pole pairs in DQ coordinate system. Plot the maximum torque $\tau_e(N.m)$ as a function of $\omega(rad/s)$ for quadrature control and for optimal field weakening in the presence of voltage and current limits. Let the parameters be $R = 0.6\Omega$, $L = 2.54$mH, $K = 0.4$N.m, $n_p = 50$, $V_{MAX} = 80$V, $I_{MAX} = 6$A, and let ω range from 0 to 400 rad/s. Plot separately the optimal field weakening current i_d.

   (b) Consider the case where both the voltage and current limits are reached. It is then possible to solve for the variables i_d, i_q, v_d, v_q and to find the positive torque that is obtained in that case as a function of ω. However, a solution may not exist for all values of speed. Plot the torque as a function of speed where a positive solution is possible, and discuss how the solution could be combined with the results of part (a) to obtain an optimal strategy for all speeds.

   (c) Consider the case when $v_d = 0$, and derive the expression for the maximum positive torque available within the voltage and current limits. Plot the torque as a function of speed, and observe that the torque is much lower than the torque available using the other strategies.

   Hint: for part (b), it is useful to define Z, φ, and δ such that

$$\begin{aligned} i_d &= I_{MAX}\cos(\delta), \quad i_q = I_{MAX}\sin(\delta) \\ R &= Z\cos(\varphi), \quad n_P\omega L = Z\sin(\varphi) \end{aligned} \tag{1}$$

   With these definitions, the voltage limit yields an equation of the type

$$\sin(\varphi + \delta) = x \tag{2}$$

   If $|x| \leq 1$, δ can be determined, and i_q and τ_e derived from δ. Note that the asin(x) function of Matlab gives the value of $\varphi + \delta$ in the $-\pi$ to π range. There is another possible value equal to $\pi - \text{asin}(x)$ to be considered in the solution.

3. Courses notes. Problem 3.3.