Assignment 7: Motor Analysis and Selection

24-370 Engineering Design I
Due @ 12:30, Wednesday March 16th 2011

Please turn in this assignment electronically by replying to the soliciting email. You will need to combine your answers into a single PDF file with Matlab code, figures, and written responses.

Part 1: Dynamic Motor Analysis in Matlab

The following problems use the sample code discussed in lecture. This code can be downloaded from the course website under Lecture Notes. There are four matfiles: motorcontrol.m is a script that runs the motor simulation; motorodefun.m is an ode function that takes the time and state of the motor system as inputs and returns the state derivative as an output; voltagefun.m is a function that calculates the voltage applied to the motor based on the time and state of the system; and torquefun is a function that calculates the externally-applied torque on the output shaft of the motor or gearbox based on time and state.

1.a - Fill in the blank. It turns out that certain parts of the code are missing! Find these broken pieces and fill in the correct code. There are 5 lines with missing code. Be sure to check your equations for consistency in sign, e.g. of the applied torque. Include printouts of these edited matfiles in your answer sheet.

1.b - No load response. Set the motor voltage to the nominal voltage and the externally applied torque to zero by editing votagefun and torquefun, respectively. Run the simulation by typing motorcontrol in the command window. Be sure that the current or local path (the file directory at the top of the command window) is set to the directory where you saved the matfiles. Please give your answer to the following questions to three significant digits:

> 1.b.i - What is the peak current draw and when does it occur? You may find this by typing [maxI,i] = max(I) followed by t(i).
>
> 1.b.ii - What is the terminal velocity of the motor output shaft? You may find the final velocity by typing dtheta(end)
>
> 1.b.iii - What is the final current through the motor? Please round to the nearest 1e-5 Amps.
>
> 1.biv - Please briefly explain the observed qualitative trend in current over time. Include in your explanation a reason for the peak value and time, as well as for the final value.

1.c - Constant-speed powering. Now set the externally applied torque so as to slightly resist motor rotation. This is akin to lifting a mass against gravity. In torquefun, set the constant torque to -0.01 (or positive 0.01, depending on how you have defined the torque in your motorodefun equations). Run motorcontrol, and obtain the following to three significant digits:

> 1.c.i - What is the peak current draw and when does it occur? How does this compare to 1.b.i?
>
> 1.c.ii - What is the final velocity of the motor and how does this compare to 1.b.ii?
>
> 1.c.iii - What is the final current through the motor, and how does it compare to 1.b.iii?

1.c.iv - What is the instantaneous electrical power being consumed by the motor at the end of the simulation? The final mechanical power? What, therefore, is the electromechanical efficiency of the motor at this speed and torque?

1.c.v - How much mechanical work did the motor perform against the external load over the course of the simulation? You can determine this using the command trapz(t,Pm), which performs a trapezoidal numerical approximation of the time integral of the mechanical power. How much electrical energy was consumed? What was the overall efficiency? Why is this different from the answer in 1.c.iv?

1.d - Gearbox effects. Now implement the effects of having a non-unity gear ratio and imperfectly efficient power transmission in the gearbox. In motorodefun, change the physical plant dynamics to reflect these influences. Remember that the gear ratio will affect the relationship between the external torque applied to the gearbox output shaft and the torque felt by the motor rotor. Remember also that the primary effect of gearbox inefficiency is on the torque transmitted from the motor to the gearbox output shaft. You will also need to modify motorcontrol, to reflect changes to mechanical power due to the relationship between motor velocity and output shaft velocity. Set the gear ratio to 10 and the gearbox efficiency to 0.7, then run the simulation. Please report the following to three significant digits:

1.d.i - What is the motor velocity at the end of the simulation?

1.d.ii - What is the motor mechanical power at the end of the simulation? How does this compare to your answer from 1.c.iv? What is the reason for this difference?

1.d.iii - Increase the output torque by a factor of 10 and re-run the simulation. What is the electromechanical efficiency under this mode of operation? Why is it different from the efficiency in 1.c.iv? What parameter would you need to change to obtain identical effects?

1.e - Bonus question. For up to 20 bonus points, find the constant output torque that would result in the maximum mechanical power output for this motor. Please hand in all of your code, as well as plots and numerical values that support your claim.

Part 2: Motor Selection

Find a commercially-available motor with the same physical parameters as presented in the Matlab example above. You will find such a motor at maxonmotor.com. Go to Brushed DC Motors, under Online Catalogue. You will be presented with an active spreadsheet that allows you to arrange catalog motors by their primary properties. From our power analyses, we can guess that the rated power is around 5 Watts. It turns out that the exact rated power is 6.5 Watts. From there, you should be able to find the desired motor. If more than one motor seems to satisfy the requirements, choose the stock version. Please report the catalog item number (found under “Order Number”).