Michigan Tech
MEEM/EE 4295: Introduction to Propulsion Systems for Hybrid Electric Drive Vehicles

HW-4
Topics: Driver Input, Torque Limits, Model Based Design (Simulink)

Model Based Design Exercise

In HW: 1-2, the tractive force necessary to meet a specific drive cycle was calculated WITHOUT consideration of the tractive force and powertrain limits. In HW-3, you added a powertrain with limits on available power and torque, limits on tractive forces based on vehicle/road interaction, plus a finite ratio transmission (FRT). In HW's 4-10, a linear vehicle dynamics subsystem, an E-drive and IC engine subsystem, transmission and differential subsystem, and driver subsystem will added to the Simulink model. The E-motor will be added with a single speed final drive ratio (differential ratio) and a single speed reduction prior to the differential. We can modify the gear ratio to the E-motor in our post transmission, pre-differential architecture if needed.

Using the Simulink code from HW-2 as a starting point, and knowege of traction limited performance, add the following.

1) Build a subsystem for the longitudinal vehicle dynamics that with a main input of the tractive force and the velocity and acceleration as the output. An example of the subsystem is shown below[1], however this is a simplified version of a complete LVD, where the max tractive is set from the static conditions.

Figure 1 : The Linear Vehicle Dynamics subsystem to used in the Hybrid Vehicle Model

[1] We are not using jet engine in the LVD, it is just a cool icon.

The subsystem has for inputs the tractive force at the front and rear and the road slope. The “guts” of the LVD uses the equations from the FBD, determines the maximum tractive force, acceleration and then outputs the acceleration. This will be used later in the Driver Control Subsystem, Battery Subsystem, etc.

2) Add a Driver Controller and use it with the E-drive motor to provide the requested torque (think tractive force) at the wheels to follow a given drive cycle. As part of the validation process, use it to predict the position, velocity and acceleration of the vehicle after a 10 second drive cycle operating at the E-Drive equivalent of the WOT from HW-3. You may modify HW-3 have numbers to compare to HW-4.

For the Driver Controller, start with a PID. You may wish to use just the P (no ID) to develop a “feel” for a system that will follow a path. A Brake Subsystem will be added later.

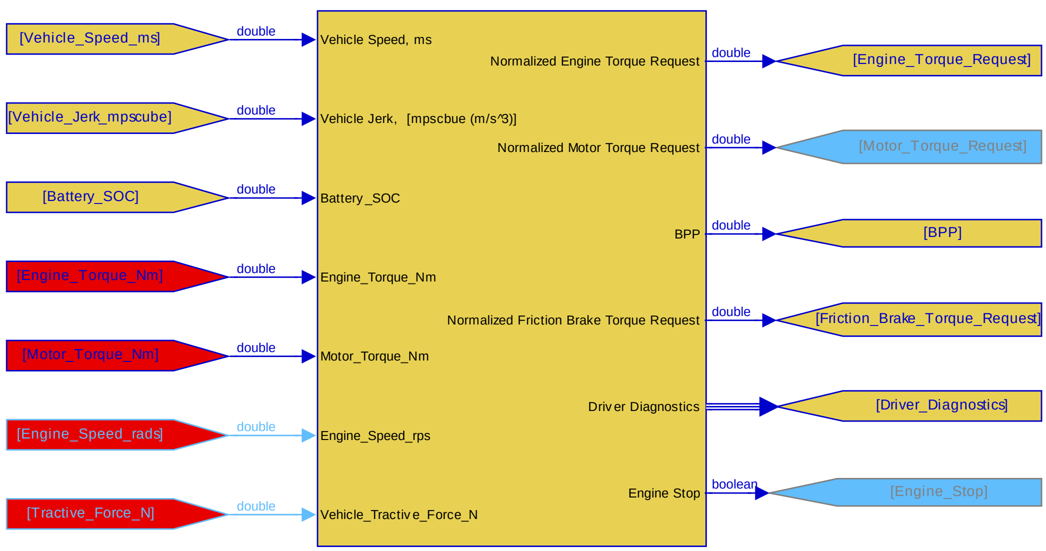

Figure 2: An example of a Driver Controller. Most of the inputs will be added in later home works. This will become part of your Hybrid Vehicle Model or HVM.

3)

The Torque versus Rotational E-Motor Speed for a “typical” electric drive motor is shown below. It is for a PowerPhase 150 manufactured by UQM used in numerous MTU Hybrid Vehicles. For this assignment, you may model the torque as a constant value to the start of the constant power curve, about 1,100 rpm. At the start of the approximately constant power curve, use a straight line to approximate the torque from 1,100 rpm to 5,000 rpm. Approximate the slope and intercept. An “easy” way to model the torque is with an embedded Matlab function. You will be able to set conditions for the various torque curves in the embedded function using standard conditional statements.

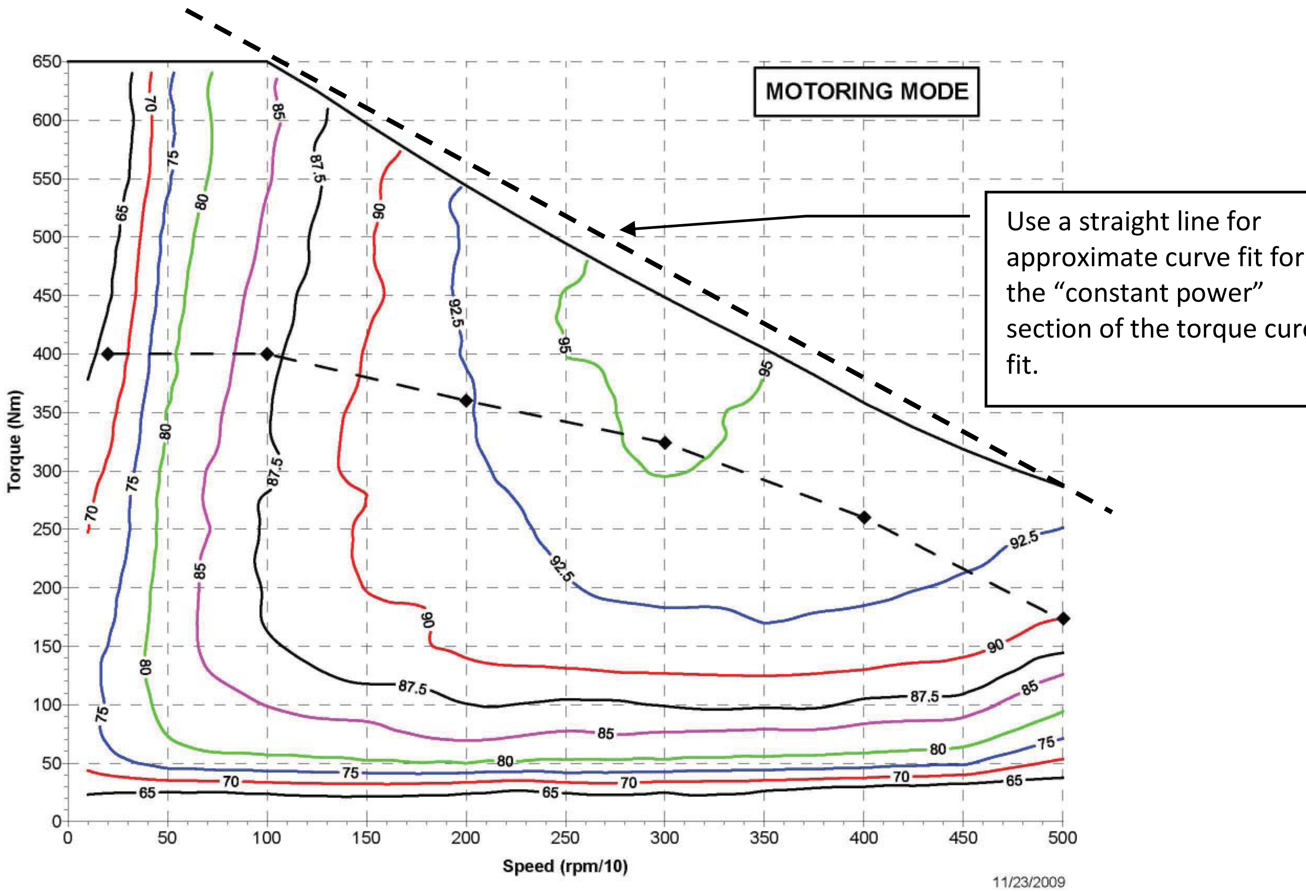

Figure 3: Torque curve for the E-Motor, note the scale on rpm.

4) Two drive cycles for HW-4 will be provided. You will be notified via e-mail when they are available.
   a) A general drive cycle, MTU_Local_2011.xls. Use this cycle to “debug” your Simulink Model.
   b) An individual drive cycle, each student will be provided their own drive cycle.

5) Use your Simulink model to:

a) Control your electric vehicle over a drive cycle. Note that it is not yet a “real hybrid,” although it has the potential to recover energy. You will add the IC engine in later assignments and blend the torque from the two drive systems.

b) Determine the “error” between the Target Speed and Vehicle Speed. Since we do not have friction brakes, it is possible to have significant errors.

c) Determine the regenerative torque. Remember you have a 300 Volt E-Motor and may only recover 85% of the capacity of the E-Motor.

d) Plot the amps for the drive cycle, we are assuming a constant 300 Volt E-Motor and power source. The voltage in both the e-motor and battery will be variables in future assignments.

e) Determine the power needed as a function of time.

f) Plot the results for tractive force versus time.

g) Validate the code. Hint: use basic physics and constant acceleration for some “ball park” numbers.

Weight (N)	16,000
Wheel base (meters)	3.04
b, distance to front tire from cg (meters)	1.4
Tire radius (meters)	0.410
h, height to cg from ground (meters)	0.450
Rolling resistance coefficient	0.016
Drag coefficient	0.44
Cross sectional area	2.7 m^2
Air density	1.224 kg/m^3
Final Differential Ratio, N_D	3.08
E-Motor Gear Ratio, N_{EM}	TBD (your choice)
Coefficient of friction between the pavement and the tire, m_r	0.8

Table 1: Vehicle Specifications