MECH545 - Hybrid Electric Vehicle Propulsion
Project 07 Vehicle Fuel Energy Requirements – Variable Efficiency
Dr. Craig Hoff

HEV Objective: The purposes of this project are (a) to improve the vehicle fuel energy model developed in Project 06 by including variable fuel converter efficiency and (b) to understand fuel converter operating conditions during standard driving cycles.

MATLAB/Simulink Objectives: Learn to: (a) use a Simulink 2-D Lookup Table block, (b) use a saturation block to avoid zero-divides, and (c) learn to add a 'scatter' plot on top of a contour plot

Problem Statement: For this project (and for all the remaining projects) you will <u>use the converted 2017 Audi Q7</u> from Project 02, which is 225 kg (496 lb) heavier than the base vehicle. Your task is to improve the 'simple motor' fuel energy model developed in Project 06 by accounting for variable motor/generator efficiency (rather than constant efficiency). The data for motor/generator efficiency is contained in the file *mc_UQM_PowerPhase100.m*, which is available on Blackboard. The file *Motor_plot.m* will plot the data.

An illustrative Simulink model for this problem is shown in Figure 1. The key changes from Project 6 are (1) a submodel to convert vehicle speed (m/s) to motor speed (rpm) and (2) a submodel to use the motor power and speed to determine the motor (and generator) efficiency.

Remember: We are using two motors to power this vehicle, so tractive load will be split between the two motors.

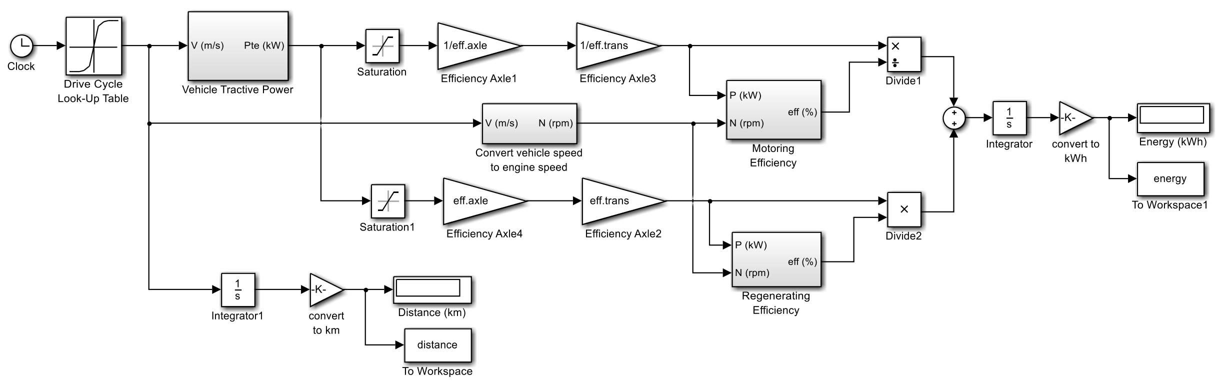

Figure 1 Illustrative solution for improved vehicle fuel energy model

Before continuing with the problem statement, recall that in Project 02 we considered a two-speed transmission, with R_{t1} = 5.0 and R_{t2} = 2.5. To avoid the need to add shift-logic to the model, we will replace the two-speed with a single speed transmission with R_t = 3.5. The resulting driveline plot is provided in Figure 2. Note that the figure indicates that the maximum speed for the vehicle is 143.4 kph (89 mph).

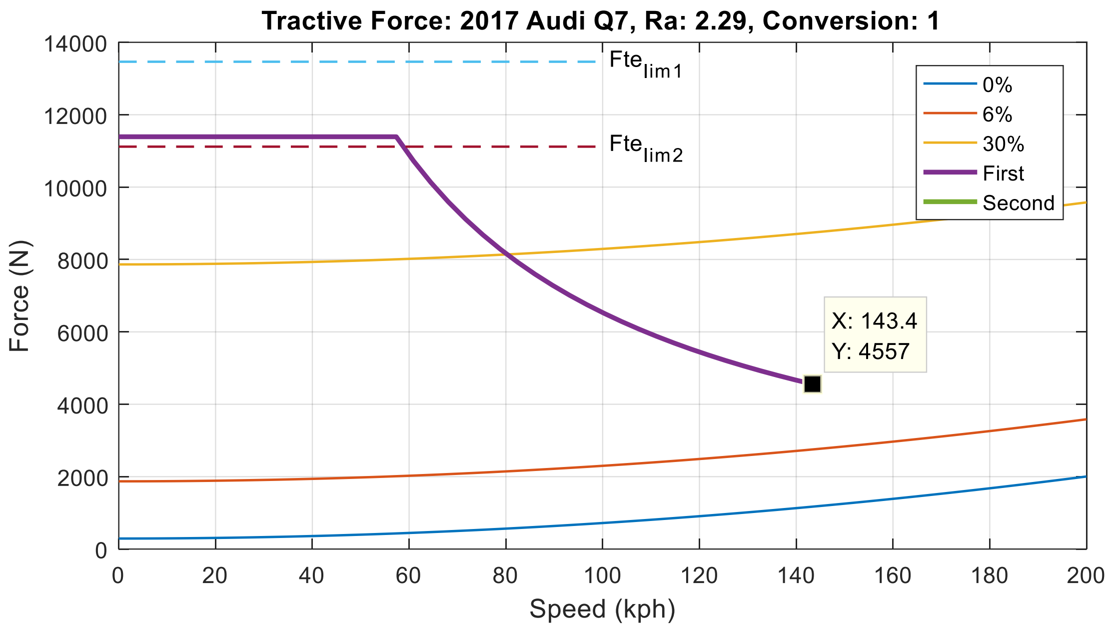

Figure 2 Driveline plot based on Project 02 with single-speed transmission (Rt =3.5)

The vehicle speeds for the three driving cycles to be considered in this project (City, Highway, and US06) are shown in Figure 3. All of these test speeds are below the 143.4 kph, so from a speed standpoint the single-speed transmission is sufficient.

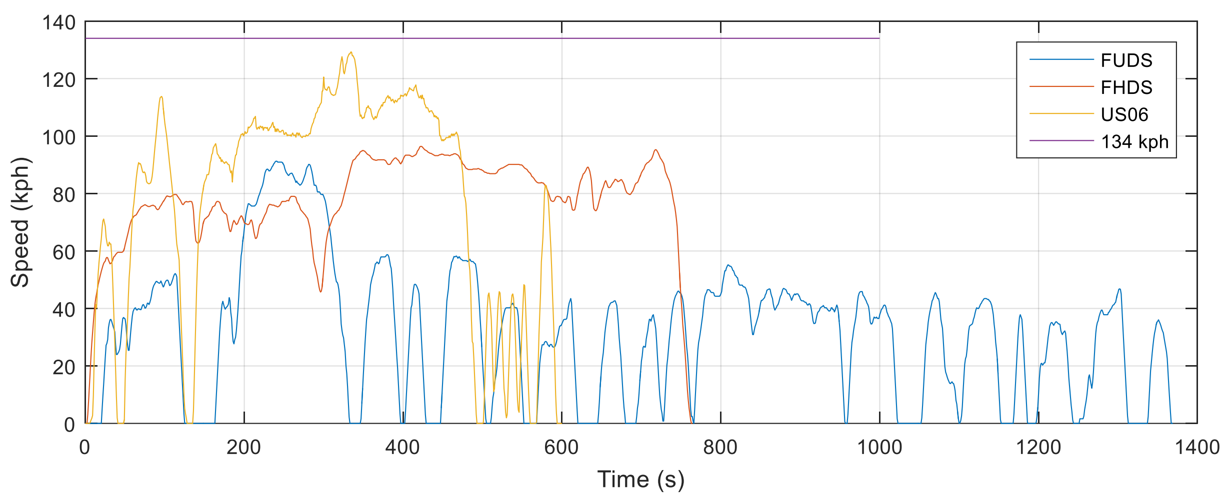

Figure 3 Comparison of the three driving cycles to be used in this assignment.

Part 1: Determine the fuel energy requirement for the converted vehicle

For this part of the assignment, assume that the vehicle is driven with the single-speed transmission. And recall that R_a = 2.29, η_a = 0.95, η_t = 0.95, r_{tire} = 381 mm, and k_m = 1.15. Use your model to determine:

a) The fuel energy required for the converted vehicle to complete the three drive cycles in electric mode
b) The reduction in energy consumption compared to the base vehicle
c) The weight of the battery pack required for a range of 100 km, assuming that the specific energy for the battery pack is 0.080 kWh/kg. (Note: this is the same as the first generation Chevrolet Volt – 16kWh/200kg)

Complete Table 1 to summarize your results and comment on your results.

Table 1 Summary of Results

Parameter	City	Hwy	US06
Measured Energy Consumption – Base (kWh/100km)[1]	**45.8**	**46.2**	-----
Predicted Energy Consumption – Converted (kWh/100km)			
Percent Energy Savings (line1-line2)/line1 in EV mode			-----
Weight of battery pack to go 100 km (kg)			

Part 2: Create plots of motor operating points.

For each case in Part 1, create a plot of the operating points of the motor, on the motor efficiency plots. An example of such a plot for a vehicle driving the NEDC driving schedule is shown Figure 4. The MATLAB command for generating a 'scatter plot' is: `plot(rpm,trq,'o')`. These plots can also be used to match the motor to the chassis; the goal is to have the operating points to be predominately in the high efficiency operating region.

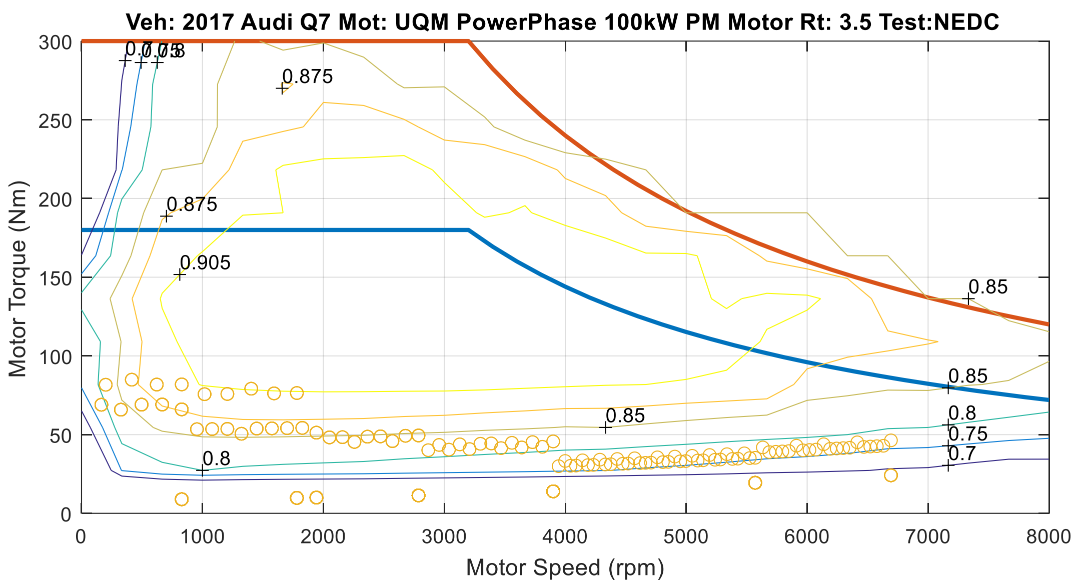

Figure 4 Motor operating points during the NEDC city driving cycle.

[1] Estimated from EPA fuel economy guide values

Question – Is this motor capable of powering the vehicle on all of these drive cycles? If not, can the problem be corrected by changing the gear ratio?

Part 3: <u>MECH-691Students (MECH-545 Students for Extra Credit)</u>
Repeart your previous work, but modify your model and allow the transmission to shift between the original first and second gear. To assist you with this modification, I have provided two shift control blocks in the file: "TwoSpeedShiftControllers.mdl." The second block (Shift Control StateFlow) is my preferred option, but it requires that you have a Simulink Add-on called StateFlow. If you are using Kettering computers or if you have the student version of MATLAB/Simulink you should be able to use this block[2]. If this block does not work, the first block (Shift Control Simulink) should work on any version of MATLAB/Simulink. Both blocks will produce the same result.

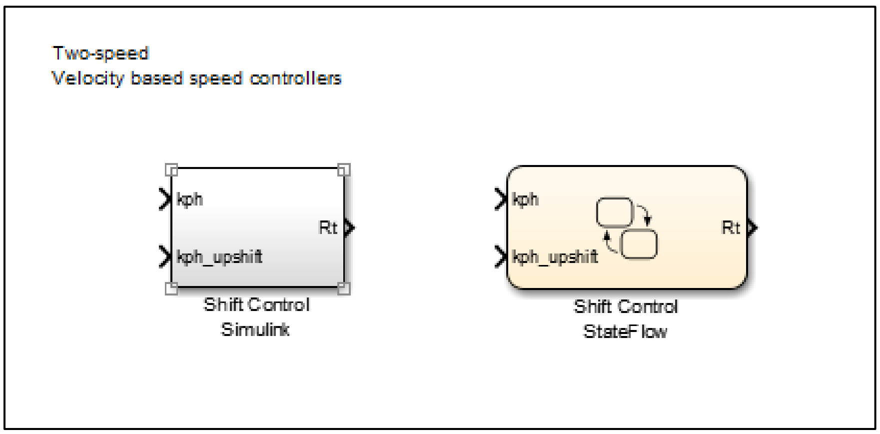

Figure 5 Two-speed shift control models in the file "TwoSpeedShiftControllers.mdl"

The shifting strategy being using is very simple.

- If the vehicle is in first gear and the vehicle speed exceeds kph_upshift, shift up to second gear. From the solution to Project 02, a good option for kph_upshift is 100 kph. Below this speed first gear produces more torque than second gear. Use a constant block to set the kph_upshift value.
- If the vehicle is in second gear and the vehicle speeds falls below [kph_upshift – 5 kph], shift down to first gear. The offset between the upshift and downshift speed is referred to as "hysteresis" and is used to prevent the transmission from "hunting" with the vehicle is driven near the upshift speed. The 5 kph offset is built into the model.

You'll need to modify the controller block, so that the output from the controller blocks will be either (R_t = 5.0 or R_t = 2.5) depending on the gear. See the file "Information on the TwoSpeedShiftController Blocks" for more informaiton.

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[2] The Student version should allow you to run the block, but you will not be able to edit it.

Modify Table 1 so that you can compare the effects of using a two-speed shifter. Discuss any obvious differences in the operation points and how they might be affecting your answers.