**Application: Series PHEV Model Questions**

Starting with the EV model developed in the previous module, develop a series hybrid vehicle model. The driver model should generate an APP input to the motor as well as a brake pedal position (BPP) that leads to a brake system. The brake system should use a paramter to control the split between friction brakes and regen commanded to the motor. *Remember to properly scale the regen torque commanded to the motor to achieve the proper regen tractive force fraction.* The motor model used in the T-S EV model must be modified to accept a regen torque command in addition to an APP. The torque output by the motor should be calculated as the maximum motor torque at current speed times the APP percentage minus the regen torque command. The battery, driveline, and glider models can stay the same. The following models should then be added:  
  
**Engine Model:** The engine model should take a mechanical power output command which controls the output of the model. The engine should calculate fuel energy used by solving for Pin. The engine should also take in an on/off command generated by the HVSC. When commanded to "off" the engine should output no mechanical power and the losses should also be zero (including C0 term).  
  
**Generator Model:** The generator model should take as input mechanical power in (from the engine) and calculate electrical power out. This should be done using a power loss model similar to the motor model developed in the EV model and solving for Pout. The generator should also take in an on/off command from the HVSC. When commanded to "off" the electrical output to the battery should be zero and the losses should also be zero (including C0 term). The electrical output power of the generator should be subtracted from the electrical output node of the battery. The maximum mechanical power input to the generator should be limited to 50 kW peak (one minute) and 25 kW continuous.  
  
**Hybrid Controller (HVSC):** This model will be the control strategy of the vehicle to manage battery state of charge (SOC). The input to the HVSC should be the battery SOC and the output should be the on/off command for the genset, and a mechanical output power command to the engine. The hybrid control strategy should be a charge sustaining load following strategy. Charge sustaining means the total battery energy used (difference between final and initial SOC) should be less than 1% of fuel energy used for a drive cycle. You may need to iterate on the initial SOC and hybrid controller parameters until you get a result that meets the criteria. A load following controller could be achieved with a simple PID controller that looks at the difference between current and target SOC and commands genset power. However, this simple SOC control does not minimize fuel consumption. Remember you cannot command more power than the generator is capable of and you   
should not command negative power to the genset(no engine start details). The hybrid controller must maintain the battery SOC between 30 and 50 %. Your strategy should “try harder” as the battery gets farther away from the target 40% charge-sustaining SOC.

Use the following parameters and run the UDDS, HwFET, and US06 drive cycles then answer the questions.  
  
Vehicle Parameters:  
Coefficient of Rolling Resistance (c\_rr): 0.01   
Coefficient of Drag \* Frontal area (CdAf): 0.76 m2   
Air Density (rho): 1.2 kg/m3   
Vehicle Mass (m): 2050 kg  
Inertial Mass (mi): 1.04\*m   
Road Grade (%): 0   
Gravitational Constant (g): 9.81 m/s2   
Accessory Load (AccyLoad): 0.60 kW  
Maximum Brake Force (BrakeF\_max): 10 kN  
  
Motor Model Parameters:  
Max Torque: 300 Nm  
Max Power: 125 kW  
C0 = 0.6 kW, C1 = 0.02, C2 = 0.0015 1/kW (Part 1)  
kc = 0.12, ki = 0.01, kw = 1.2e-5, C = 600 (Part 2)  
  
Battery Model Parameters:  
Maximum Energy Capacity: 8.8 kWh  
SOC initial: 45%  
SOC minimum: 15%  
Voc = 340 V, Rint = 0.08 ohm  
  
Driveline Parameters:  
Constant Spin-loss: 3.6 Nm  
Gear Ratio: 7.17  
Tire Radius: 0.324 m  
  
Regen Brake Fraction: 0.55

Examine the effect of changing the regen braking fraction on the fuel consumption of the vehicle. Does changing the regen braking fraction have a larger impact of some drive cycles than others? Why?



Attempt to charge balance your series PHEV. Although this is not a mandatory step, it is good for evaluating the consumption of your model. To do so, you will need to use a while look to simulate the model multiple times, iterating the initial SOC until the net change in battery energy is less than 1% of the fuel energy over a cycle.

