AVTC Model Based Design Curriculum Development Project

M O D E L - B A S E D

DESIGN CURRICULUM PROJECT

An Introduction to Modeling an Energy Storage System (ESS)

Lesson 6.2
PHEV Supervisory Control Model

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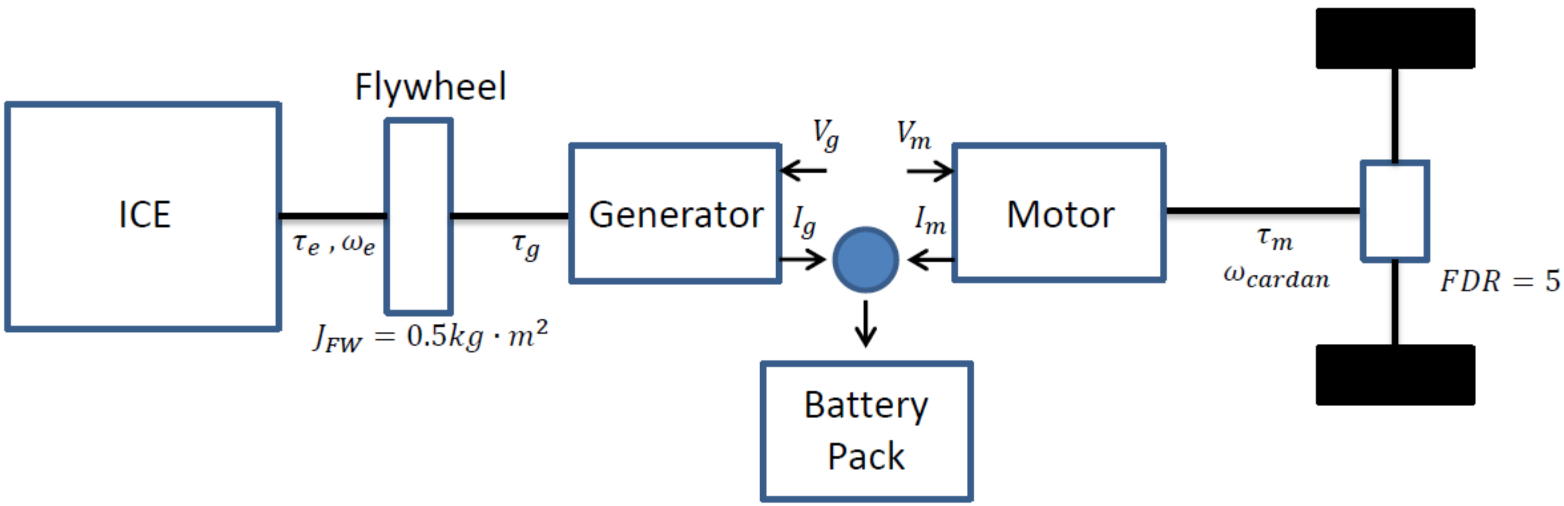
MODEL-BASED
DESIGN CURRICULUM PROJECT

Series PHEV Simple Model



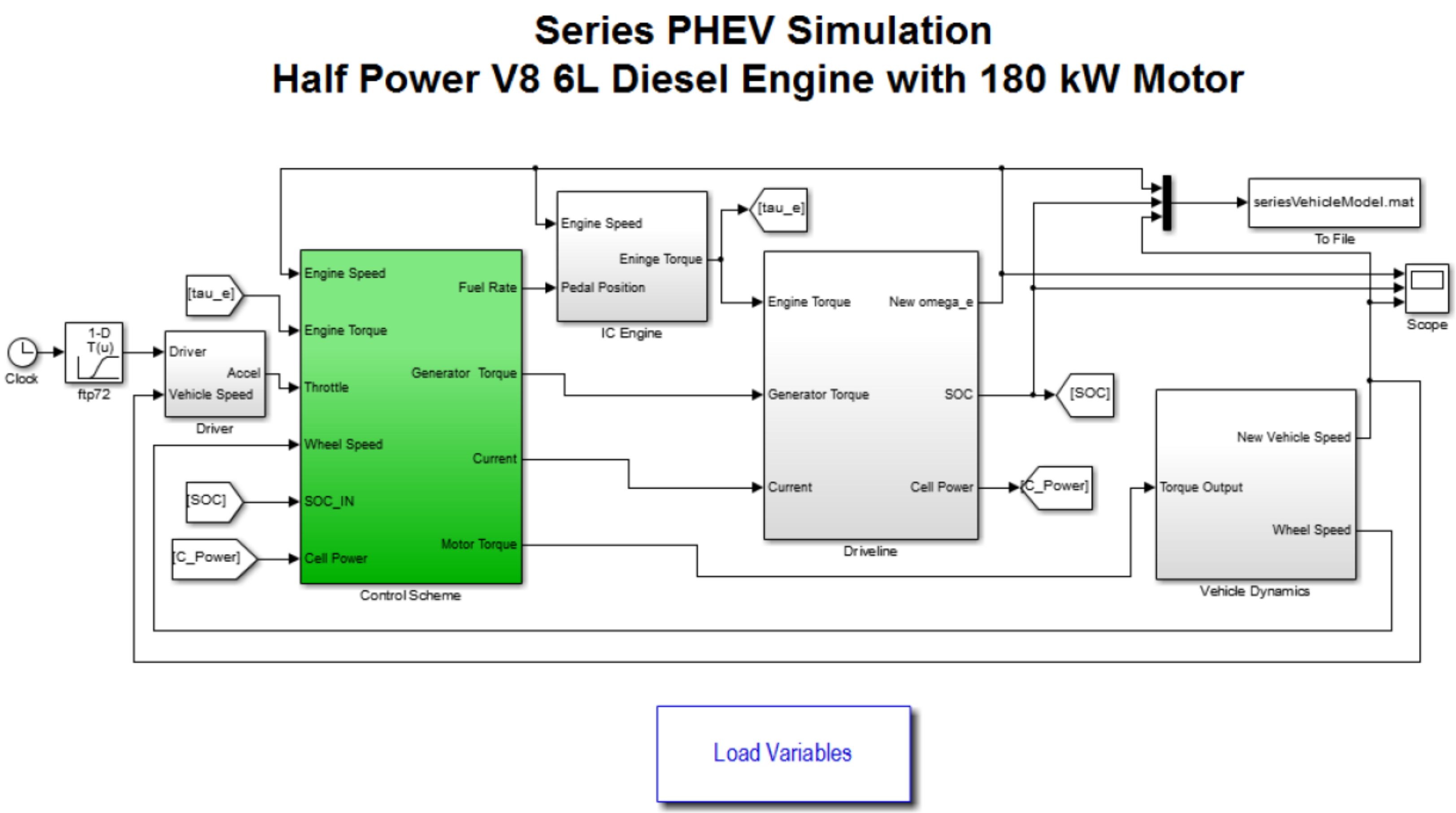
3 Equations of Motion

$$\dot{\omega}_e = \frac{\tau_g - \tau_e}{J_{FW}}$$

$$\dot{U} = \frac{F_{road} - F_{roll} - F_{drag}}{mass}$$

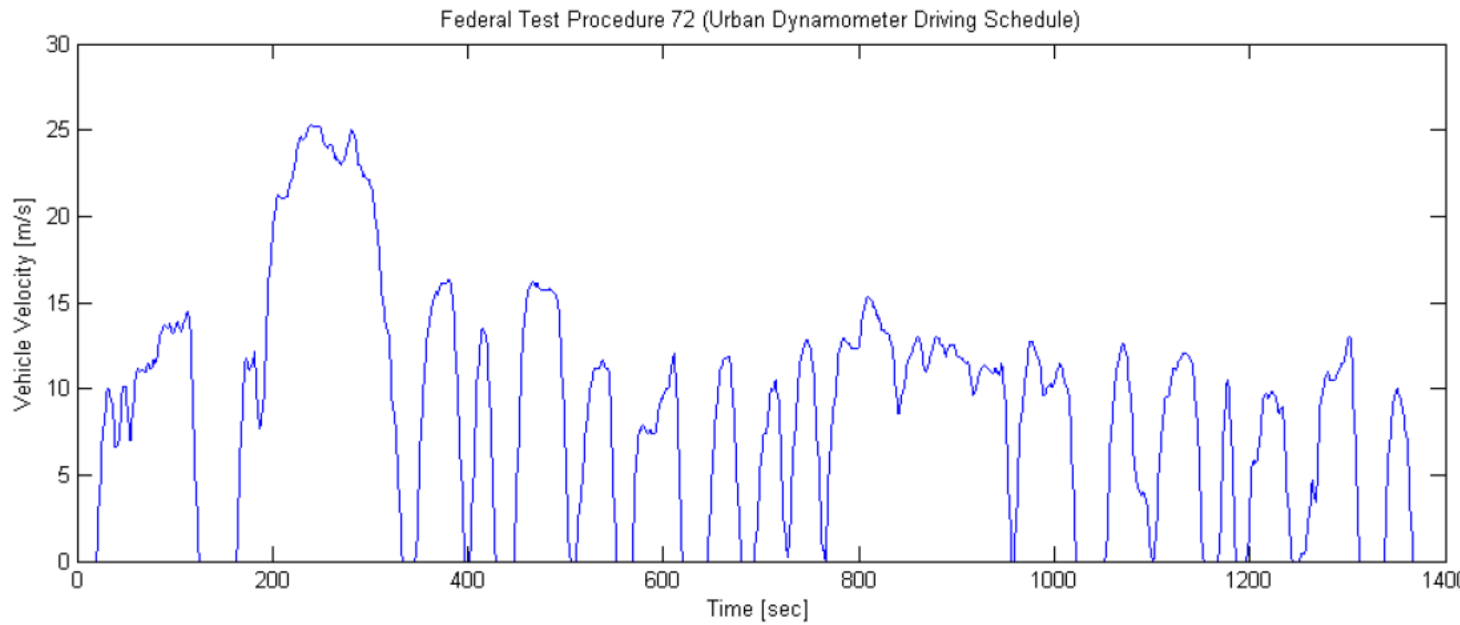
$$S\dot{O}C = \frac{I_{cell}}{Q_{cell}} = \frac{Battery\ Cell\ Current}{Battery\ Cell\ Capacity}$$

Series PHEV Full Model with Supervisory Controller



Federal Test Procedure 72 Drive Cycle

This test allows for the comparison of fuel efficiency over an urban driving schedule.



Distance Traveled ≈ 7.5 miles

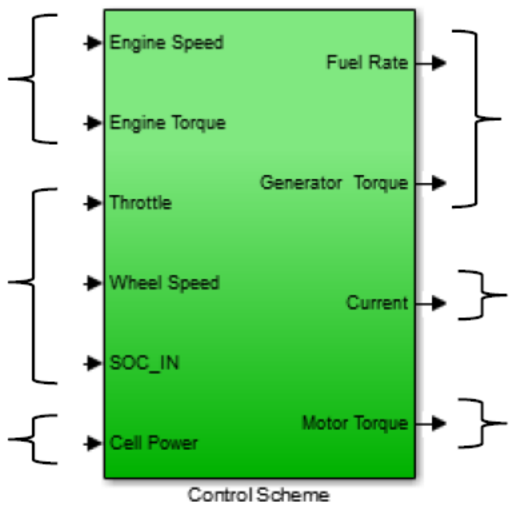
Time ≈ 23 minutes

Controller Inputs & Outputs

Actual engine speed and torque values for error calculation and control

Motor power demand and filtered ICE power demand

Actual cell power for error calculation and control

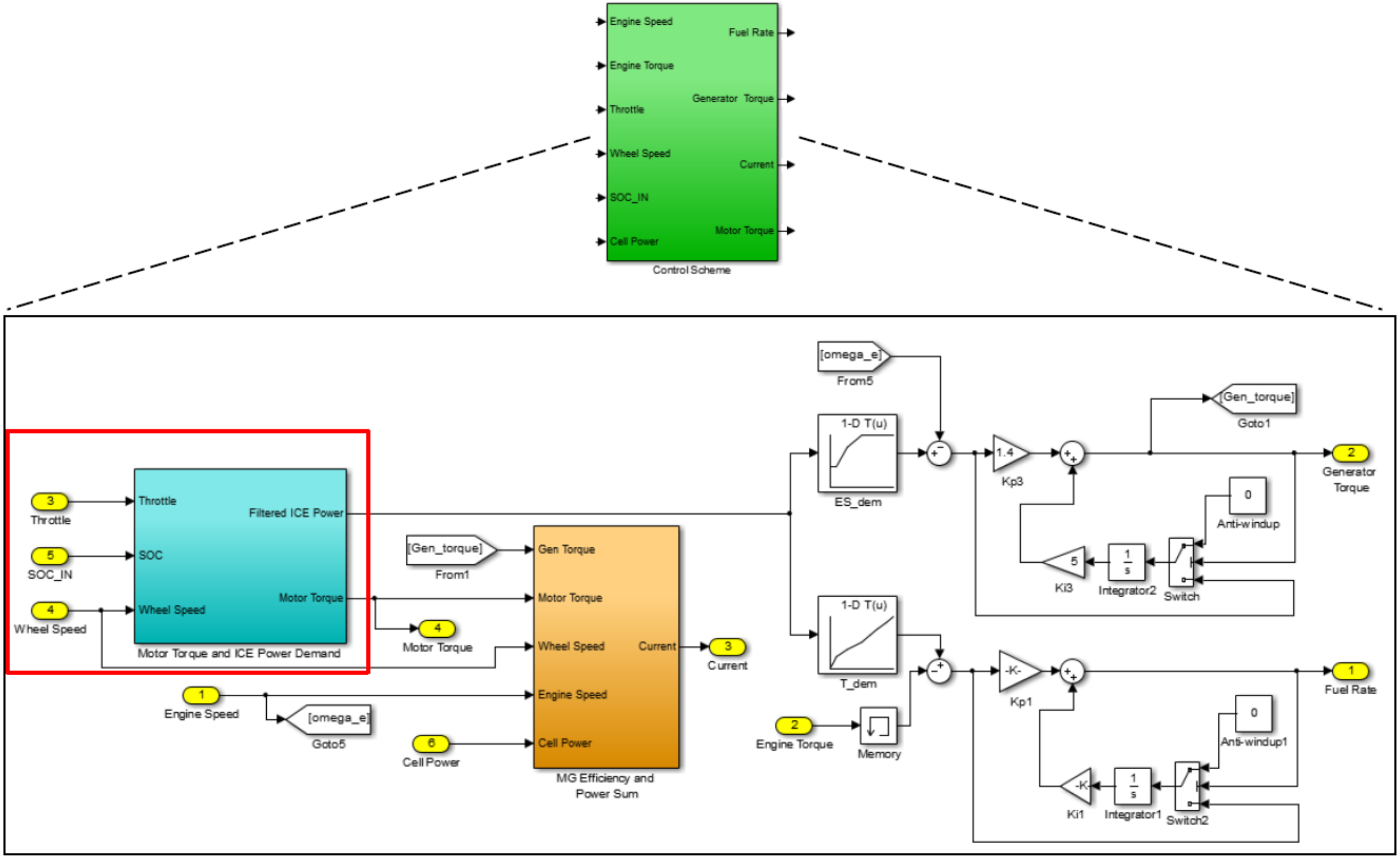


ICE torque and speed control

Battery control signal

Drive command sent to determine vehicle dynamics

Control Strategy Subsystem Outline

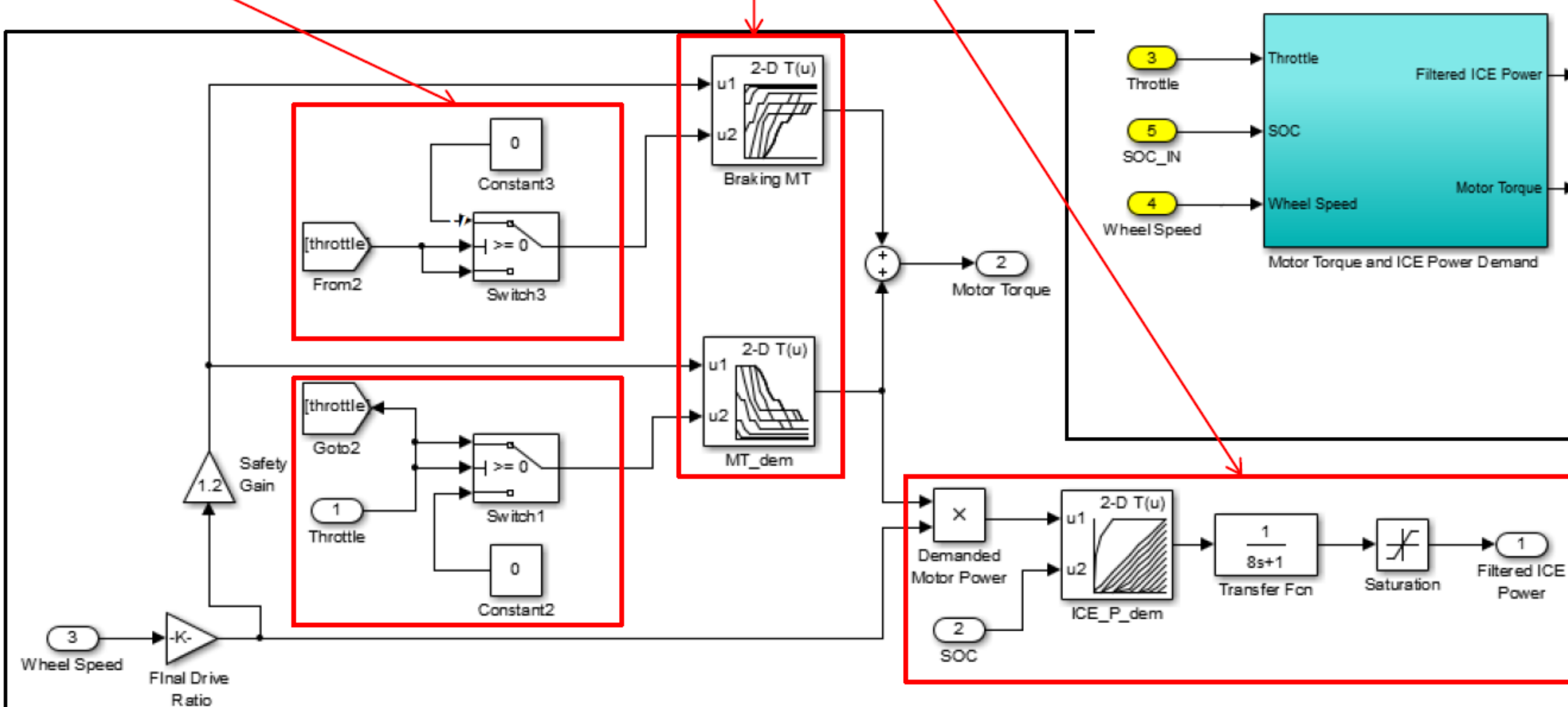


Motor and ICE Power Demand

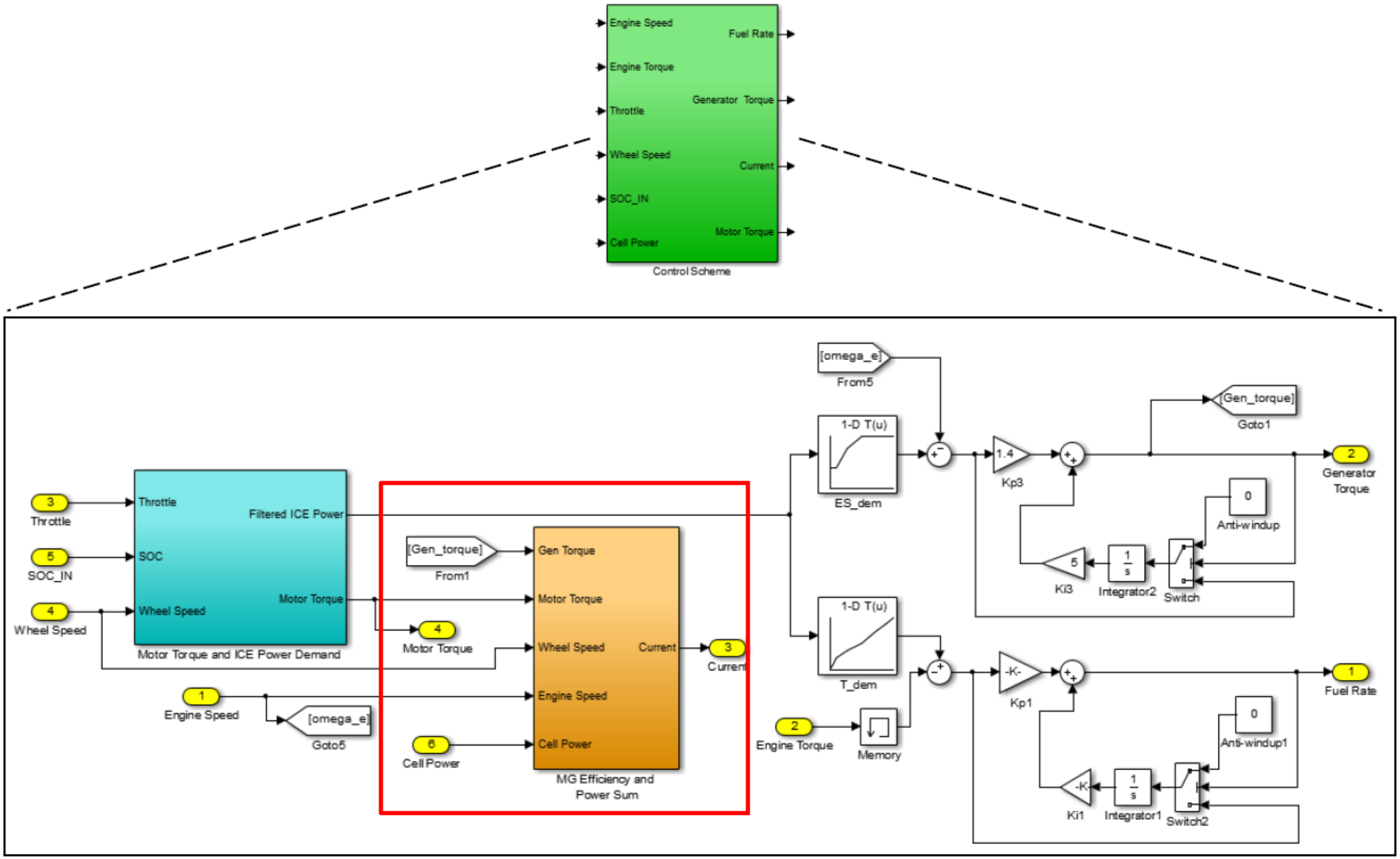
Switches determine if the throttle command is for acceleration (positive), or deceleration (negative).

Throttle and speed inputs to these look-up tables determine the demanded motor output torque.

The demanded motor power and the battery SOC are the inputs to the look-up table and the output is filtered to determine the demanded ICE power.



Control Strategy Subsystem Outline



Equations for Motor and ICE Power Demand

- The equation for power demand of the motor (P_{m_dem}) requires torque (τ_m)and angular speed (ω_m).

$$P_{m\_dem} = \tau_m \omega_m$$

- The actual motor power (P_{m_act}) is determined by either dividing or multiplying torque and speed by the motor efficiency (η_m).

$$P^+_{m\_act} = \frac{\tau_m \omega_m}{\eta_m} \quad \rightarrow \quad \text{Acceleration } (P^+_{m\_act} > P_{m\_dem})$$
$$P^-_{m\_act} = \tau_m \omega_m \eta_m \quad \rightarrow \quad \text{Deceleration } (P^-_{m\_act} < P_{m\_regeneration})$$

- The generator power (P_{gen}) is determined in a similar method as above by multiplying the generator torque (τ_g) and speed (ω_g) by efficiency.

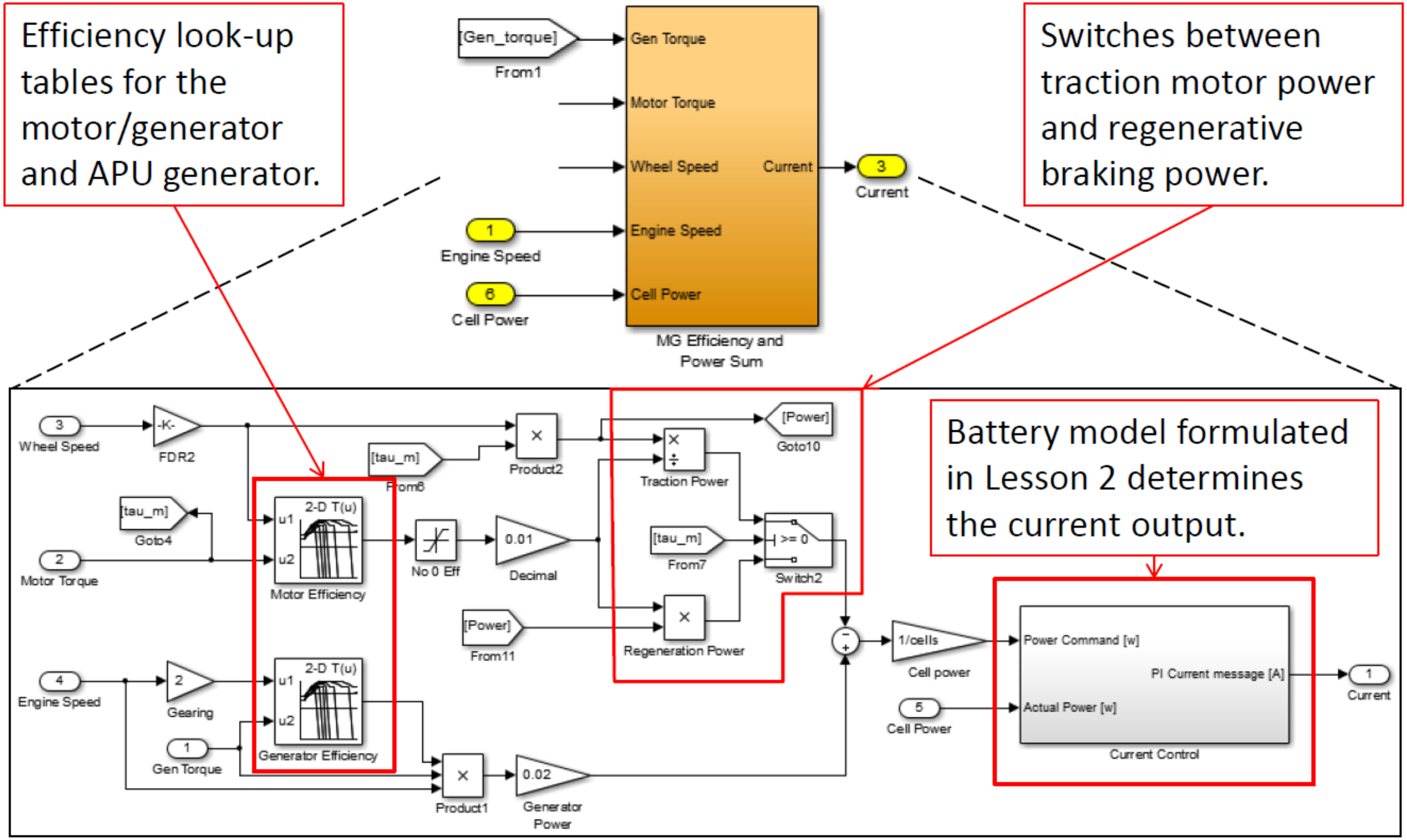
$$P_{gen} = \tau_g \omega_g \eta_g$$

Control Strategy Subsystem Outline

Efficiency look-up tables for the motor/generator and APU generator.

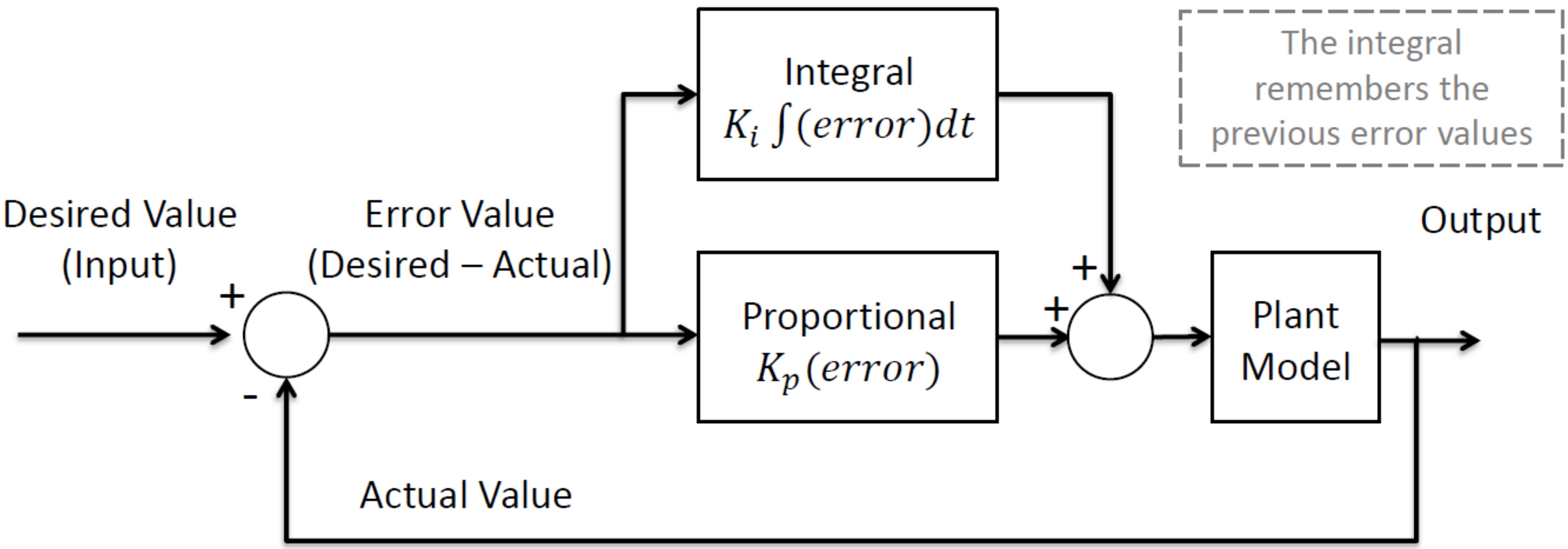
Switches between traction motor power and regenerative braking power.

Battery model formulated in Lesson 2 determines the current output.



Proportional Integral (PI) Control

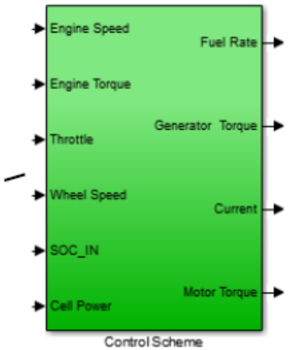
The purpose of a PI controller is to decrease the error value to zero as quickly as possible while remaining stable using current and previous error values.



The added integral component makes sure the error reaches zero, which where the actual value reaches the desired value without leaving any bias (offset value).

Control Strategy Subsystem Outline

PI control of the ICE torque by varying the liquid fuel rate.



PI control of the ICE speed by varying the generator torque.