ECE 51018 – Hybrid Electric Vehicles

Project 1 Description

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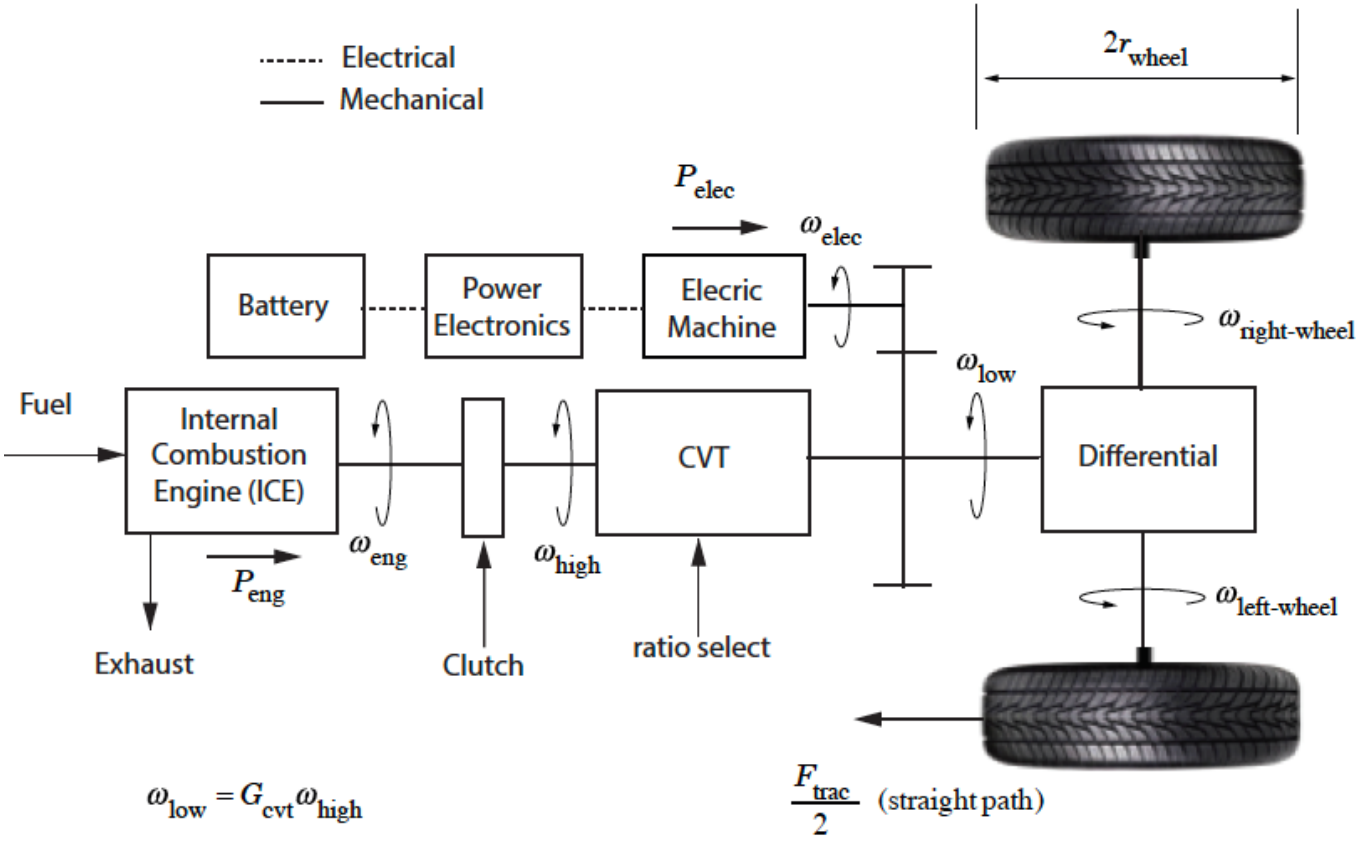
January 29, 2021

Project 1



$$\omega_{low} = G_{cvt}\omega_{high}$$

$$\omega_{right\text{-}wheel} = \omega_{left\text{-}wheel} = \omega_{wheel} = G_{diff}\omega_{low}$$

$$v_{veh} = r_{wheel}\omega_{wheel}$$

$$\omega_{low} = G_{elec}\,\omega_{elec}$$

Parameters

Table 1: Vehicle parameters

Parameter	Symbol	Value
vehicle mass w/o battery, passengers, or driver	M_{veh}	1746 kg
wheel radius	r_{wheel}	0.2794 m
electric machine gear ratio	G_{elec}	1
transmission gear ratio (min)	$G_{\text{cvt,min}}$	0.5
transmission gear ratio (max)	$G_{\text{cvt,max}}$	TBD
differential gear ratio	G_{diff}	0.268
rolling resistance coefficient	C_0	0.015
aerodynamic drag coefficient	C_D	0.35
frontal area	A_F	1.93 m^2
energy storage subsystem capacity	E_{ess}	2 kWh
energy storage subsystem round-trip efficiency	η_{ess}	0.8
minimum engine speed	$\omega_{\text{eng,min}}$	1000 rpm
minimum engine power	$P_{\text{eng,min}}$	10 kW
maximum engine power	$P_{\text{eng,max}}$	85 kW
initial SOC	SOC_{init}	0.5
gravimetric density of gasoline	m_{gas}	0.75 kg/liter

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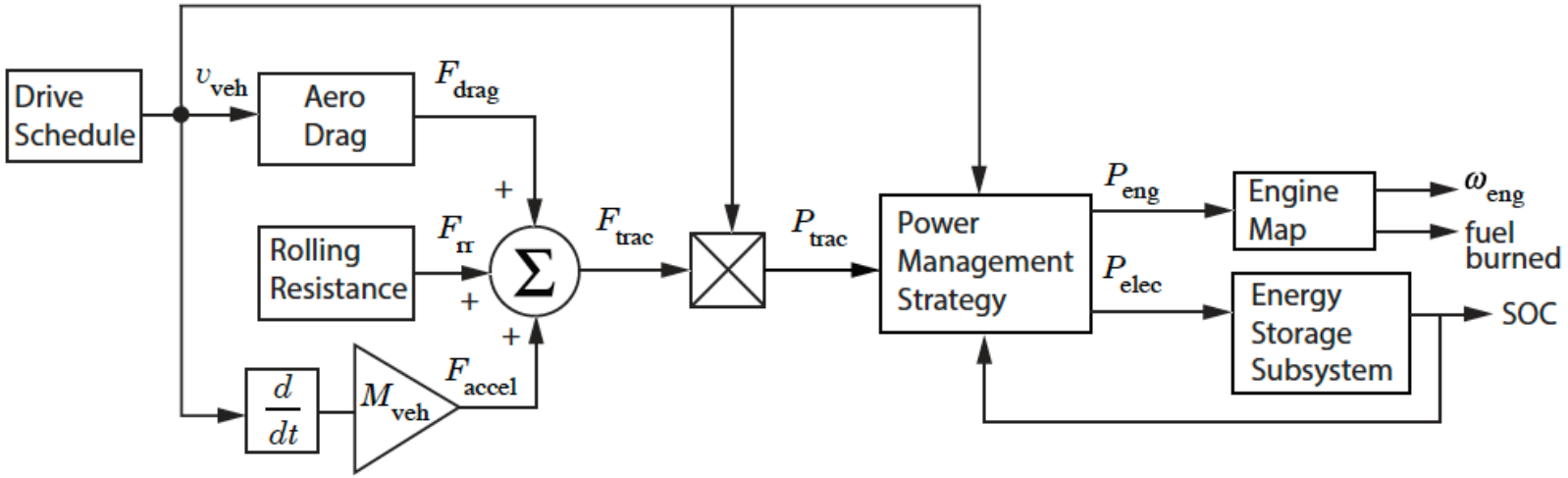
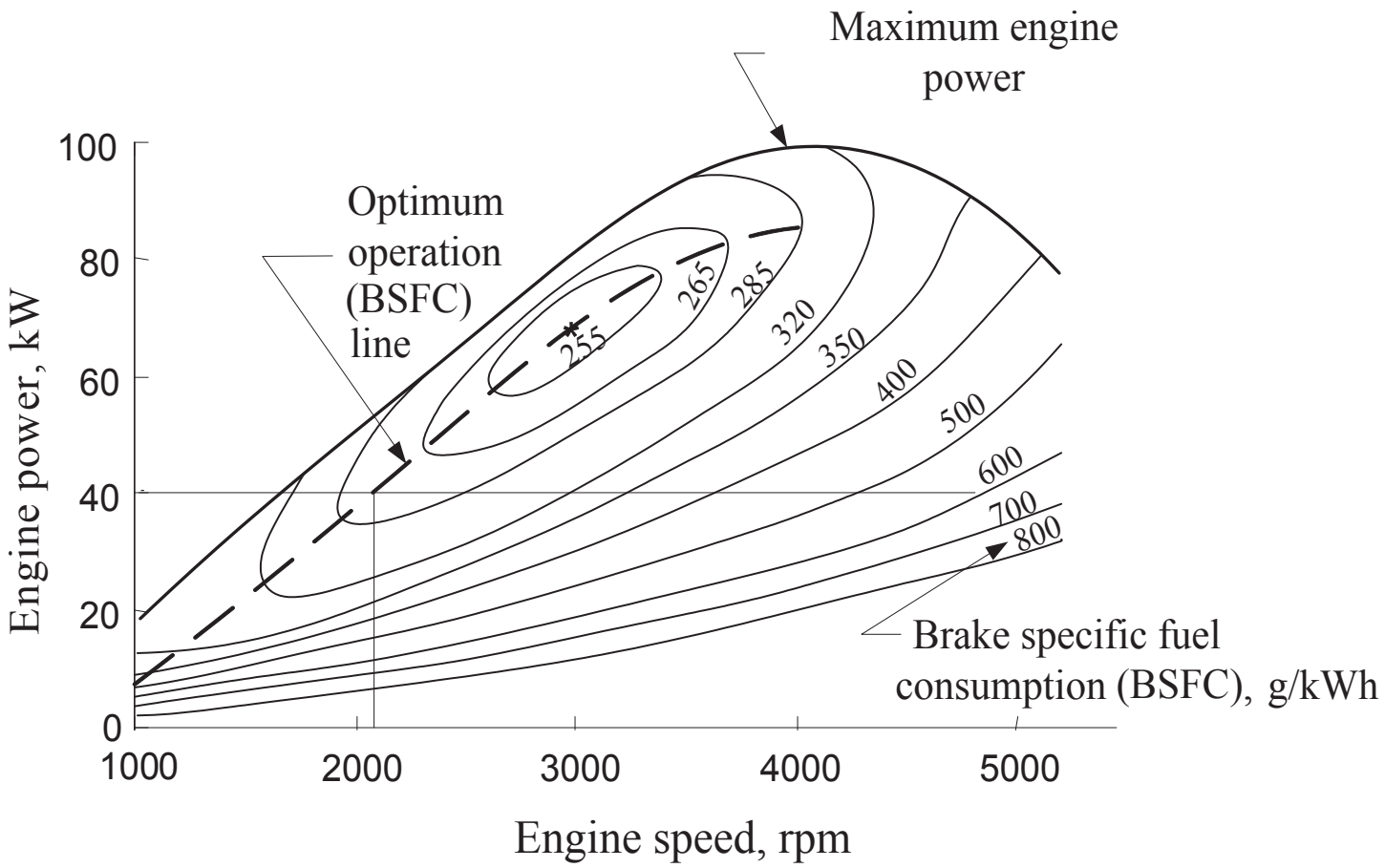


Figure 2: Top-level simulation block diagram.

Engine Map


Maximum engine power
Optimum operation (BSFC) line
255
265
285
320
350
400
500
600
700
800
Brake specific fuel consumption (BSFC), g/kWh
Engine power, kW
0
20
40
60
80
100
1000
2000
3000
4000
5000
Engine speed, rpm

Optimum Engine Power Versus Speed

Table 2: Engine optimum speed and BSFC vs power

Power (kW)	Speed (rpm)	BSFC (g/kW-hr)
7.66423	1009.3	500
12.7737	1183.18	400
24.635	1588.89	320
35.7664	1936.6	285
47.6277	2318.13	265
57.2993	2612.71	255
77.7372	3371.09	255
82.8467	3685.23	265
85.5839	4014.0	285

Variables to be plotted

Table 3: Variables to be plotted

Variable	Symbol	Unit
engine speed	ω_{eng}	rpm
engine power	P_{eng}	kW
electric machine power	P_{elec}	kW
electric machine speed	ω_{elec}	rpm
electric machine torque	T_{elec}	N-m
tractive force	F_{trac}	N
tractive power	P_{trac}	kW
battery state of charge	SOC	-

Versus time

Also plot electric machine torque versus speed.

Power Management

1. If the vehicle speed is below a threshold, the clutch is disengaged and the engine is shut off. The vehicle-speed threshold occurs when the CVT is operating at its lowest gear ratio $G_{\text{cvt,min}}$ and $\omega_{\text{eng}} = \omega_{\text{eng,min}}$. In this mode of operation, $P_{\text{eng}} = 0$ and $P_{\text{trac}} = P_{\text{elec}}$. This will be called electric launch mode.

2. If $v_{\text{veh}} > v_{\text{veh,min}}$ and required P_{trac} is less than minimum engine power ($P_{\text{eng,min}}$), the clutch is engaged but no fuel is provided to engine ($P_{\text{eng}} = 0$). In this mode, $P_{\text{elec}} = P_{\text{trac}}$. A positive P_{trac} is supplied BY the electric machine (making it a motor) while a negative P_{trac} means that mechanical power is supplied TO the electric machine (making it a generator). The latter case is known as regenerative braking. The CVT ratio is contrlled so that $\omega_{\text{eng}} = \omega_{\text{eng,min}}$. This will be called all-electric mode.

3. If P_{trac} is greater than maximum engine power along the optimum BSFC line (85 kW), assume $P_{\text{eng}} = P_{\text{eng,max}}$. In this mode, $P_{\text{elec}} = P_{\text{trac}} - P_{\text{eng,max}}$. This will be called electric boost mode.

4. Whenever $v_{\text{veh}} > v_{\text{veh,min}}$ and $P_{\text{eng,min}} < P_{\text{trac}} < P_{\text{eng,max}}$, we will try to bring the SOC back to 0.5 by charging or discharging the battery at a rate of 4 kW. Initially, we will try using $P_{\text{elec}} = 4000 \times \text{sign}(\text{SOC} - 0.5)$ and $P_{\text{eng}} = P_{\text{trac}} - P_{\text{elec}}$. If the calculated P_{eng} falls below $P_{\text{eng,min}}$, the clutch remains engaged; however, fuel is shut off ($P_{\text{eng}} = 0$) In this case, the CVT ratio is controlled so that engine speed is $\omega_{\text{eng,min}}$. This will be called the charge-sustaining mode.

Approximate SOC Estimation