Drive Train Control Systems

„ Individual Remote Work“ of BEV Model

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Content

Methodology and Explanations

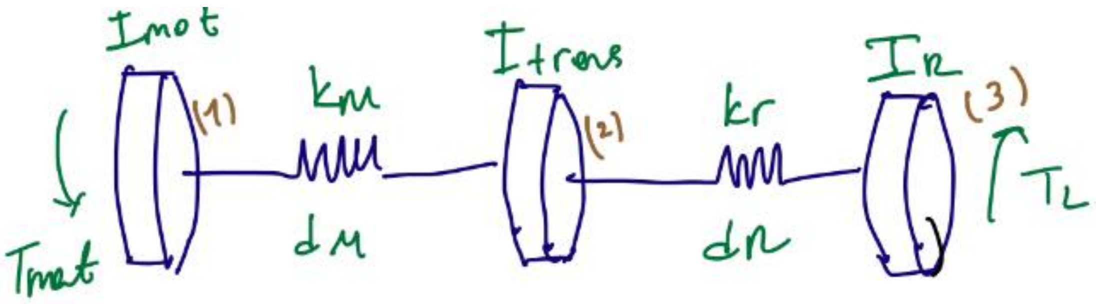
Objective

- ➢ Model the driveline of a Battery Electric Vehicle (BEV)
- ➢ Design a PID control system for accurate WLTP cycle tracking

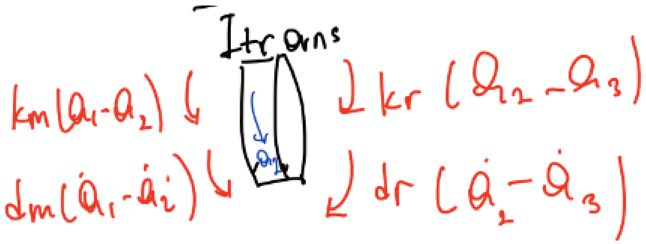
Simulink Model

- ✓ **Driveline modeling:** Simulink representation of BEV driveline components
- ✓ **Resistance modeling**: Calculation of total driving resistance (T_load)
- ✓ **Control system design:** PID control system for torque command
- ✓ **Motor Torque and Speed**: Utilizes 1D lookup table for torque-speed relationship
- ✓ **Saturation Dynamics**: Limits the torque output and braking torque of the motor
- ✓ **PID Control System**: Manages motor torque based on speed error

Calculations of BEV Driveline Model 3 DOF



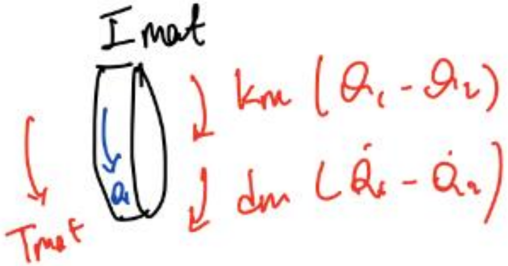
(2)



$$= k_m(\theta_1-\theta_2) + d_m(\dot{\theta}_1-\dot{\theta}_2) - \ddot{\theta}_2 \cdot I_{trans} - k_r(\theta_2-\theta_3) - d_r(\theta_2-\theta_3) = 0$$

$$= \ddot{\theta}_2 = \left(\frac{k_m(\theta_1-\theta_2) + d_m(\dot{\theta}_1-\theta_2) - k_r(\theta_2-\theta_3) - d_r(\theta_2-\theta_3)}{I_{trans}}\right)$$

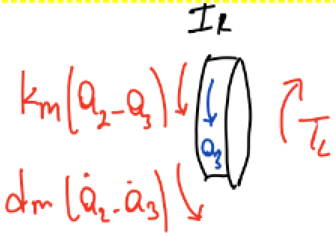
(1)



$$= T_{mot} - I_{mot} \cdot \ddot{\theta}_1 - k_m(\theta_1-\theta_2) - d_m(\dot{\theta}_1-\dot{\theta}_2) = 0$$

$$= \theta_1 = \frac{1}{I_{mot}}\left(T_{mot} - k_m(\theta_1-\theta_2) - d_M(\dot{\theta}_1-\dot{\theta}_2)\right)$$

(3)



$$= k_m(\theta_2-\theta_3) + d_m(\dot{\theta}_2-\dot{\theta}_3) - \ddot{\theta}_3 \cdot I_R - T_L$$

$$\theta_3 = \left(\frac{k_m(\theta_2-\theta_3 + d_m(\dot{\theta}_2-\dot{\theta}_1) - T_L}{I_R}\right)$$

Calculations of Driving Resistance Forces (F_z)

Driving Resistenence Equations

$$F\_R = fr \cdot m \cdot g \cdot \cos\alpha$$

$$F\_L = c_w \cdot A \cdot \frac{rho}{2} \cdot v^2$$

$$F\_a = m \cdot \lambda \cdot \ddot{x}$$

$$F_{st} = mg \cdot \sin\alpha$$

$$F_z = mg\left(fr \cdot \cancelto{1}{\cos\alpha} + \cancelto{0}{\sin\alpha}\right) + \frac{1}{2} c_w \cdot A \cdot rho \cdot v^2 + m \cdot \lambda \cdot \ddot{x}$$

(1) $$F_z = V_{mass} \cdot g \cdot fr + \frac{1}{2} c_w \cdot A \cdot rho \cdot v^2 + V_{mass} \cdot \lambda \cdot \ddot{x}$$

(2) $$\lambda = 1 + m_r / m \,,$$

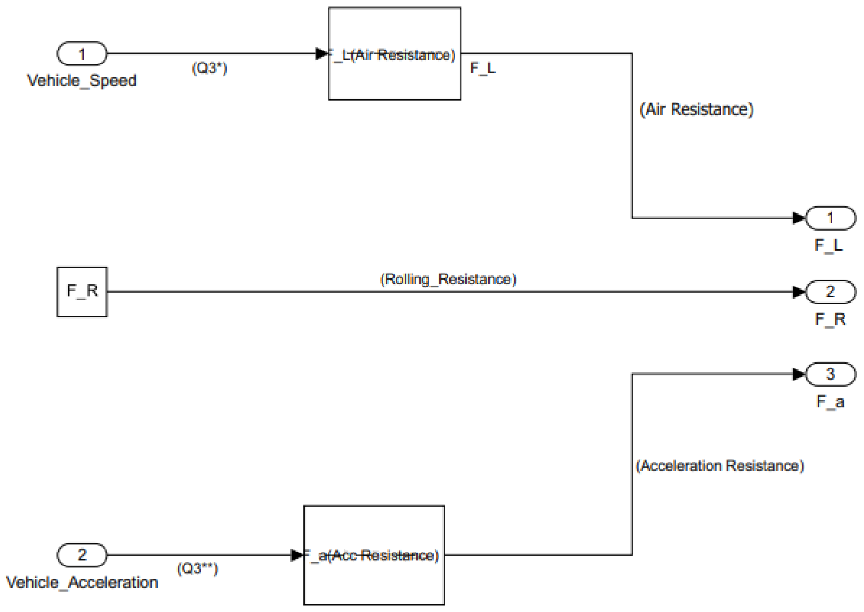
(3) $$M_r = \frac{I_{red}}{R^2_{dyn}} = \frac{I_{mot} + I_{trans} \cdot i^2_{tot}}{R^2_{dyn}}$$

MATLAB / Simulink Model

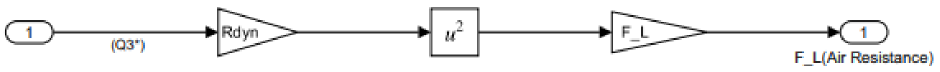
Variables.m

```
% Driveline Parameters
d = struct('T1', 400, 'W1', 300, 'T2', 200, 'W2', 500, 'T3', 100, 'W3', 1000); % Nm
rad/s

% Vehicle and Transmission Parameters
vmass = 1370; % kg
Rdyn = 0.3; % m
itot = 10.2;
Imot = 0.9 ;  %kg*m^2
Itrans = 1.2; %kg*m^2
mr = ((Imot+Itrans)*(itot^2))/(Rdyn^2);
lamba = 1+(mr/vmass);

% Stiffness and Damping Parameters
kM = 13000; % Nms/rad
dM = 6.5;  % Nms/rad
kr = 201.5;
dr = 206;

% Air and Rolling Resistance Parameters
fr = 0.019;
cw = 0.31;
A = 2.15; % m^2
Rho = 1.2; % kg/m^3
g = 9.81;
F_L = cw*A*(Rho/2); % Air resistance
F_R = fr*vmass*g; % Rolling resistance

% Simplified Vehicle Inertia
I_veh_red = vmass * Rdyn^2 / itot^2;

% WLTP Data
filename = 'WLTP.xlsx'; % File name for WLTP
data = readmatrix(filename); % Read the matrix from the file
wltp_st = [data(:,1), data(:,2)]; % Time-WLTP combination
```

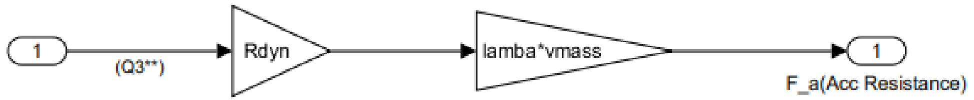
(1) Subsystem F_R:



(2) Subsystem F_L :



(3) Subsystem F_a:



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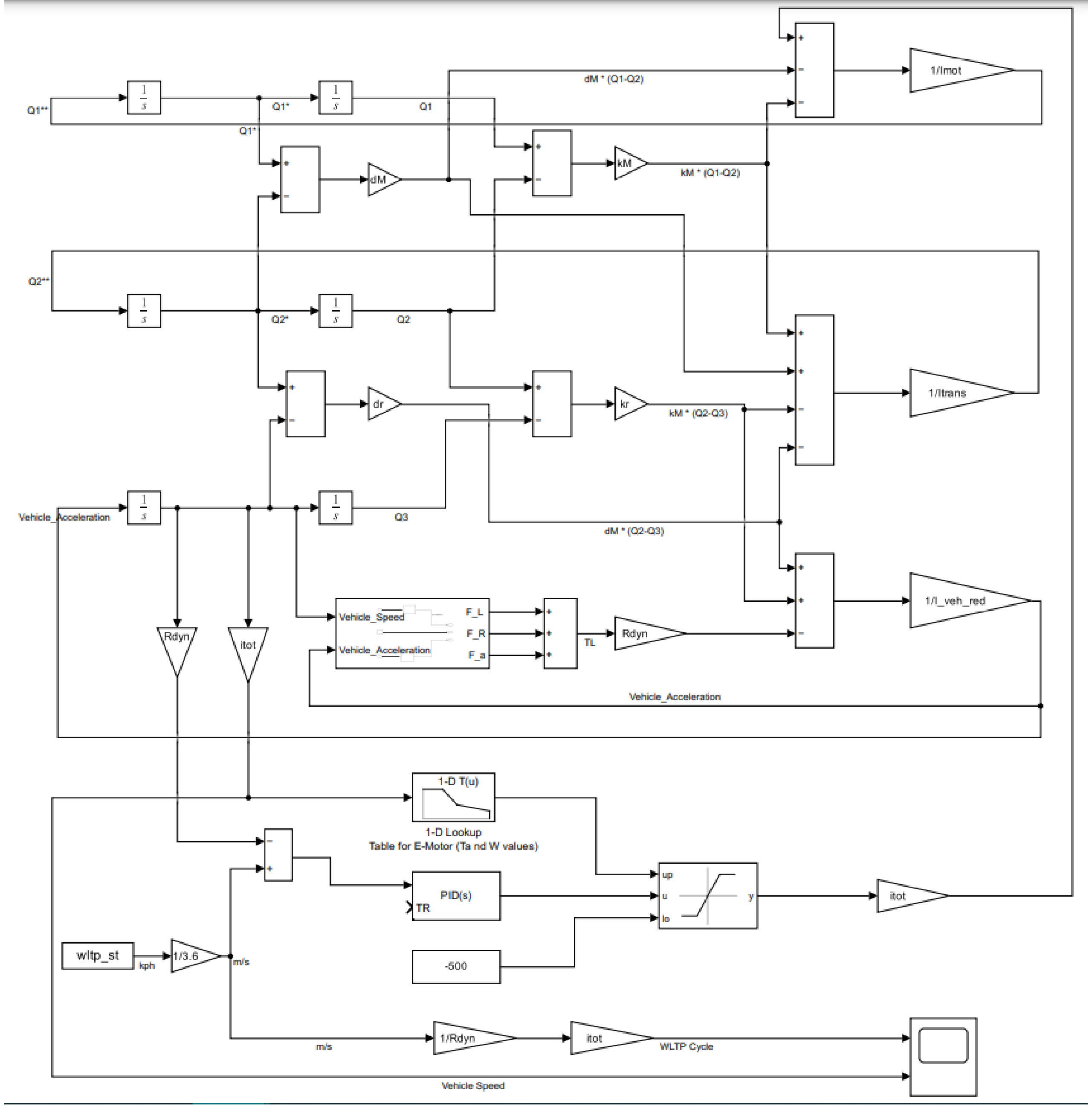
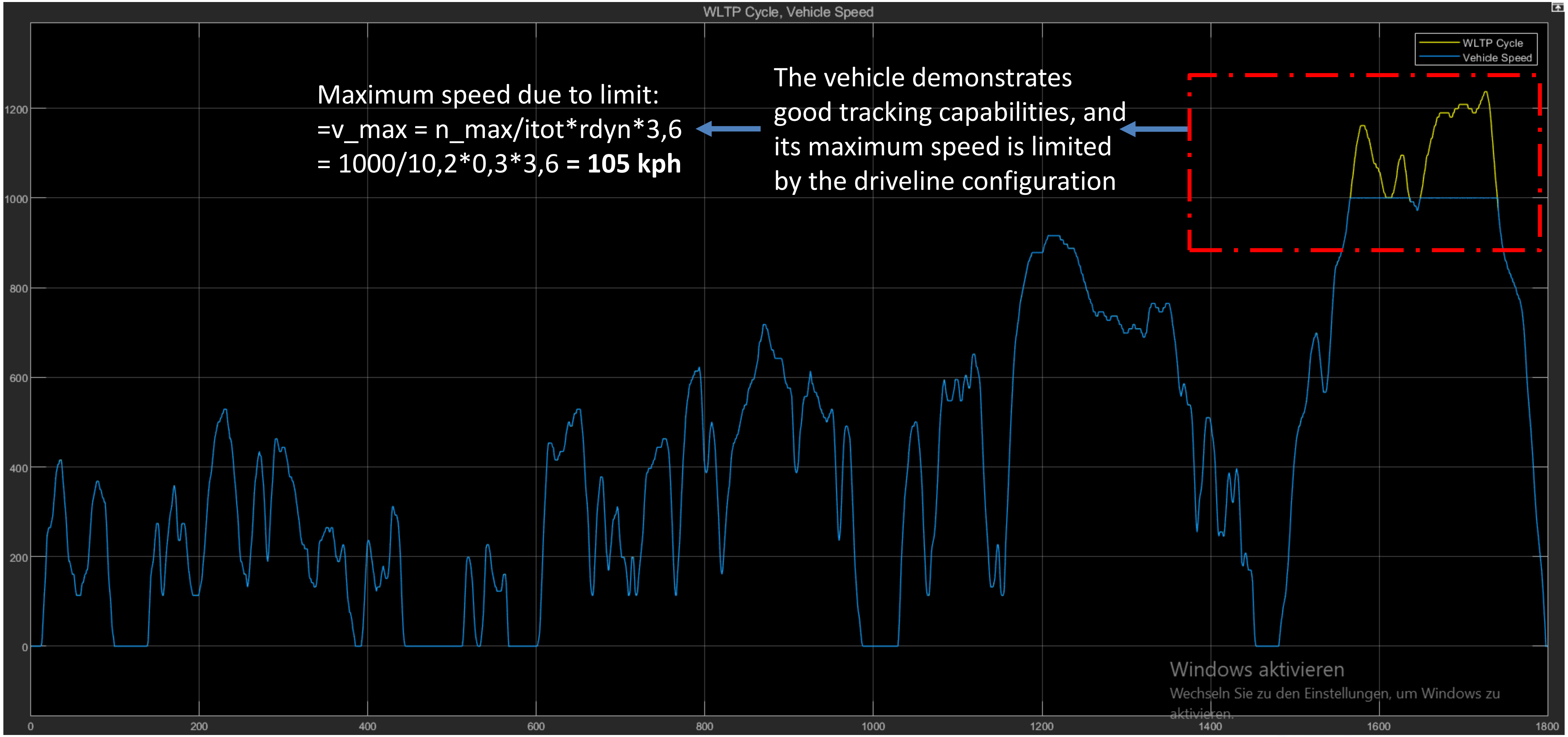
Simulink Model

Printed and bigger version is available in the "Report".



Results Scopes



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Conclusion

- **Precise Driveline Model:** Successful representation of BEV's dynamic behavior
- **Efficient PID Controller:** Managed motor torque based on speed error effectively
- **Maximum Vehicle Speed:** Conditioned by driveline parameters and observed on scope and calculated as 105 kph
- **Effective WLTP Tracking**: PID controller enables effective tracking of the WLTP cycle and demonstrated through result

THANK YOU !