Validation of acceleration specification using a basic EV simulation model

An EV is operated on a flat road and defined by the following model parameters

- r_w = 0.4 m
- M_v = 1620 kg
- C_d = 0.29
- C_r = 0.01
- A_v = 2.75 m^2
- P_{e_max} = 80 kW
- v_{base} = 30 MPH
- η_{tw} = 80% (tank to wheel efficiency, assumed constant)

a) Using approximate analytical expression, compute the acceleration time t_a from 0 to 60 MPH.
b) Solve analytically, and compute the total energy required from the battery to accelerate from 0 to 60 MPH, taking into account the tank to wheel efficiency, η_{tw}.
c) Verify the analytical result from part (a) by simulation of the model in **VehicleDynamics2.mdl** provided in **EVModel_basic.zip**. Simulate the model with the parameters above. Include the resulting plots of speed v [mph] and tractive propulsion force F_v [N] as functions of time, and the acceleration time t_a obtained by simulation.
d) Verify the analytical results of part (b) via simulation using the following steps
   - Modify the basic EV model in **VehicleDynamics2.mdl** to include the following signals
     - Vehicle tractive power P_v
     - Battery power, $P_{batt} = P_v / \eta_{tw}$
     - Total battery energy used, E_{batt} (integral of battery power)
   - Modify the **PlotEVData.m** file to add two additional subplots with the signals
     - P_v and P_{batt}
     - E_{batt}
   - Simulate the modified model and compare the results obtained by simulation with the results obtained in part (b)

System Simulation of Leaf-Sized Electric Vehicle

A driver and Nissan Leaf-sized electric vehicle are defined as given in the files contained in **EVModel_hw2.zip**, including model parameters

- $r_w = 0.4$ m
- $M_v = 1620$ kg
- $C_d = 0.29$
- $C_r = 0.01$
- $A_v = 2.75\ \mathrm{m}^2$
- $K_e = 0.407$ Nm/A
- $P_{e\_max} = 80$ kW
- $V_{base} = 32$ MPH
- $K_v = 650$ Ns
- $T_i = 50$ s
- $\eta_{DC\text{-}DC} = 98\%$ (const)
- $\eta_{inv} = 95\%$ (const)
- *Battery:* 24 kWh

The file **MotorEff.mat** contains the electric motor efficiency values as functions of motor angular speed (in rad/s) and motor torque (in N). To view the contour plots corresponding to the motor efficiency, and to find efficiency for a specific operating point, you can use the MATLAB script **PlotMotorEff.m**. Additionally, the file **PlotEVData.m** has been modified so that the motor torque T_m vs angular speed ω_m path of the vehicle is shown for the simulated driving cycle, along with the efficiency contours for the motor.

a) The nominal Nissan Leaf's gear ratio is $g_{ratio} = 7.94$. Given the vehicle speed $v = 20$ mph, find the acceleration dv/dt (in m/s^2) for which this gear ratio results in maximum drivetrain efficiency. What is the drivetrain tank-to-wheel power efficiency η_{tw} at this operating point? What is the traction power P_v at this operating point? What is the power P_{batt} supplied by the battery at this operating point? To answer these question, you do not need to run simulations of the vehicle model. You may use MATLAB to perform necessary calculations.

b) Find the gear ratio g_{ratio1} so that the drivetrain efficiency is optimized at the operating point where the vehicle speed is $v = 20$ mph and the traction power is $P_v = 30$ kW. To answer these question, you do not need to run simulations of the vehicle model. You may use MATLAB to perform necessary calculations.

c) Run simulations of the vehicle model over the driving cycle **eudc** with t_{stop}=1200, for two gear ratios, $g_{ratio} = 7.94$, and the gear ratio g_{ratio1} found in part (b).
   - Use simulation results to find for the two gear ratios.
   - Use simulation results to compare the two gear ratios in terms of the total energy taken from the battery over the course of the entire driving cycle, MPGe, tank-to-wheel energy efficiency η_{tw}, and the battery state of charge (SOC) at the end of the cycle. Turn in plots of the motor torque T_m vs angular speed ω_m path of the vehicle over the drive cycle overlaid on the motor efficiency contours.