



Electric Vehicle Simulation using MATLAB/Simulink

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Question A1: Update the given MATLAB script

MATLAB code was modified based on the data provided in the Excel spreadsheet of the vehicle being designed. The changes were made to the input parameters assigned for modification in the course assignment. The modifications include updating vehicle mass from the standard value of 2200 kg to 1956.296 kg, and updating battery nominal capacity from 355 Ah to 289.074 Ah. All other parameters including drag coefficient, frontal area, nominal battery voltage, state of charge at start and at end of the trip, and drivetrain efficiency coefficients remained constant. These changes ensure consistency between the simulation and the modeling parameters of the vehicle while allowing customization in terms of the vehicle used. With the required changes made, the code can now be used to call the Simulink model of the assigned driving cycle.

1	clc	
2	clear all	
3	close all	
4	%% Vehicle parameters	
5		
6	vehicle.mass = 1956.296 ; %'copy this from the given spread sheet';	
7	vehicle.dragCoef = 0.22; %do not change this	
8	vehicle.area = 2.4; %do not change this;	
9		
10	%% Loss coefficients	
11		
12	coef.loss = 0.93; %do not change this	
13	coef.etaTrans = 0.97; %do not change this	
14	coef.etaMotor = 0.93; %do not change this	
15	coef.etaInv = 0.94; %do not change this	
16		
17	%% Battery parameters	
18		
19	battery.Vnom = 365;	
20	battery.SocI = 93; %do not change this	
21	battery.SocE = 7; %do not change this	
22	battery.AHrat = 289.074; %'copy this from the given spread sheet';	
23		
24	%% Regenerative rate	
25		
26	regenRate = 0.65; % this factor will change to 0.65 in QC2	
27		
28	%% Driving cycle data	
29		
30	load drivingCyc_one.mat % two driving cycles will be compared, change will be required in QB/C, load accordingly	
31		
32	%% Calling simulation	
33		
34	Tend = 99999; %do not change this	
35	sim('Model_7ent2062_2026.slx') % method to call the SIMULINK model, don't change	
36		
37	%% Results - statistics	
38		
39	%See QB details on what to calculate, analyse, plot, show etc.	
40	%ask your instructor if any question	

Question A2: Setup the given Simulink model

The Simulink model was put in the same directory as the MATLAB program and the two provided driving cycles data sets in order for the MATLAB program to call the Simulink model without any file path issues. The program was run successfully, where one driving cycle was loaded and the simulation process was carried out using the command `sim('Model_7ent2062_2026.slx')`. The selection of the driving cycle was done via the program

by calling the relevant .mat file before simulating the model. The model ran without any problems using the new values of the mass and battery capacity of the EV, thus implying that there are no problems with the MATLAB program and Simulink model connectivity.

Question B1: MATLAB figures/plot for electric power demand

The electric power demand for both driving cycles has been calculated using the Power kW input inside the regeneration section of the Simulink model. As per the instruction in the assignment, the electric power demand has been graphically represented as a plot of power vs time in kilowatts vs seconds for both driving cycles. In order to make the output more presentable and clear, only a portion of the driving cycle has been included instead of showing the entire simulation period.

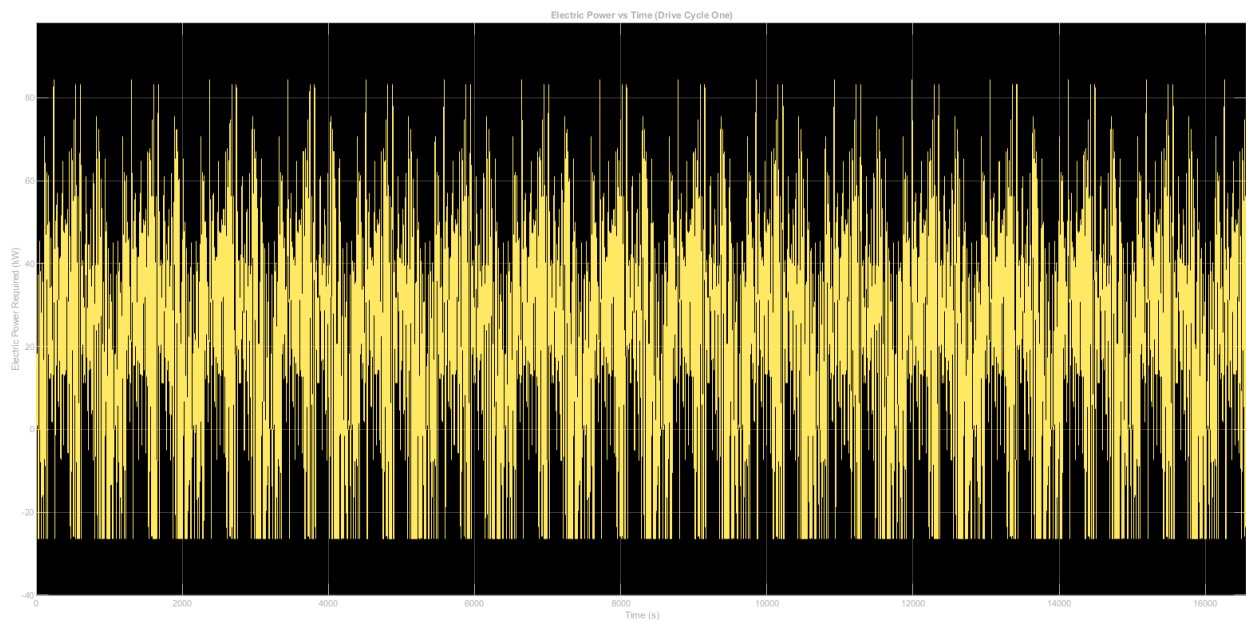


Figure 1 Electric power demand vs time for Drive Cycle 1, representative window only, x-axis = Time (s), y-axis = Electric Power Required (kW)

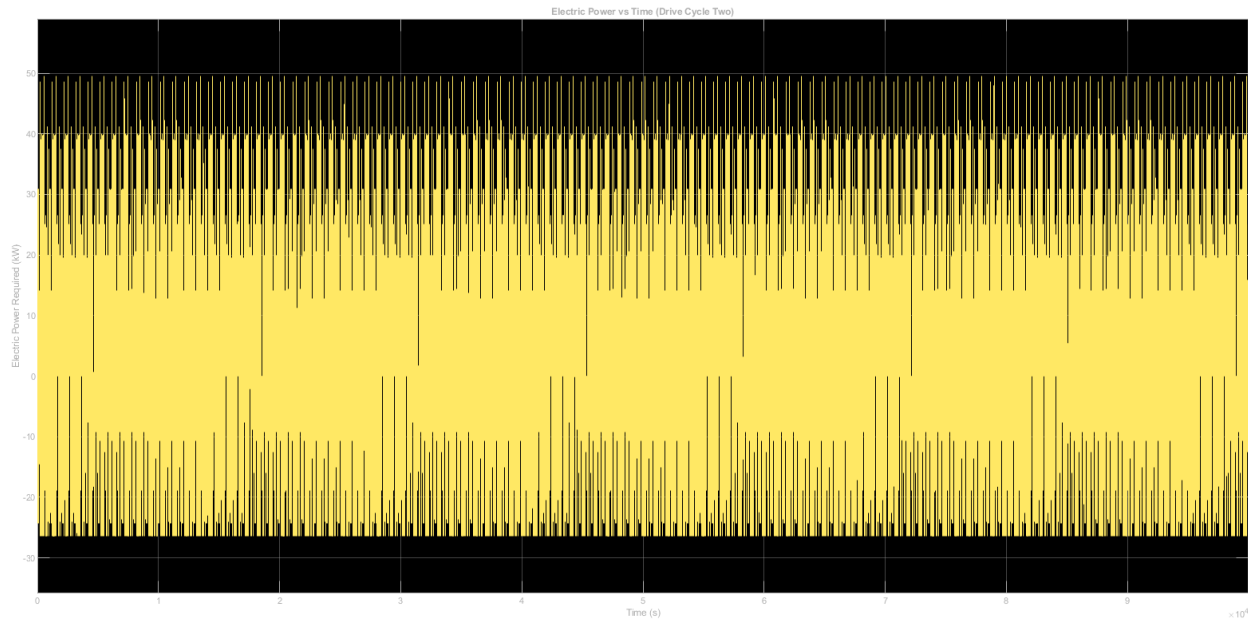


Figure 2 Electric power demand vs time for Drive Cycle 2, representative window only, x-axis = Time (s), y-axis = Electric Power Required (kW)

Question B2: Explanation of peaks and patterns in the power demand trajectory

The power consumption profiles of the two drive cycles have very different properties in terms of their peak values and overall shapes. First of all, the first cycle has a strong transient character since there are numerous spikes both positive and negative on its profile. Positive peaks represent moments of strong acceleration at which the traction motor needs to work harder to overcome not only the force of vehicle's inertia but also resistances caused by vehicle's rolling resistance and air drag, hence the increased power demand. On the other hand, negative peaks appear because of the regenerative braking process when some part of vehicle's kinetic energy turns into electric energy and gets transferred to the vehicle's battery.

Drive Cycle 2, on the contrary, has a more regular shape. It involves fewer peaks of positive and negative power, and its maximum power consumption value is smaller compared to that in Drive Cycle 1, indicating smoother conditions and less pronounced transients. Since the acceleration processes are less intense here, instantaneous power demand is smaller too.

According to the obtained power demand profiles, Drive Cycle 1 should be considered as a more urban one since it contains numerous periods of stop-and-go movement, acceleration/deceleration and has stronger changes in power demand. Also, it provides more chances to recover energy because of more prominent negative power zones. However, even with all these advantages, Drive Cycle 1 results in a smaller total range since

of the presence of acceleration periods increasing energy demand. As a consequence, Drive Cycle 2 is more efficient in this aspect.

Question C1: Energy consumption and electric range analysis

To determine the battery energy content, the nominal battery pack energy was calculated from the battery nominal voltage and ampere-hour rating:

$$E_{\text{nominal}} = \frac{V_{\text{nom}} \times Ah}{1000}$$

Using the assigned values:

$$E_{\text{nominal}} = \frac{365 \times 289.074}{1000} = 105.51 \text{ kWh}$$

The assignment asks for the **usable** battery pack capacity. Since the model uses an initial state of charge of **93%** and a final state of charge of **7%**, the usable SOC window is:

$$SOC_{\text{usable}} = \frac{93 - 7}{100} = 0.86$$

Hence, the usable battery pack energy is:

$$E_{\text{usable}} = 105.51 \times 0.86 = 90.74 \text{ kWh}$$

The electric range for each cycle was obtained by integrating the vehicle speed in miles per hour, after converting it to miles per second, until the battery reached its lower SOC threshold. Energy consumption was then calculated as:

$$\text{Energy consumption} = \frac{E_{\text{usable}}}{\text{Range}}$$

The results for the baseline regeneration setting, **regenRate = 0.25**, are given in Table 1.

Table 1 Results for electric range and energy consumption when regenRate = 0.25.

Driving Cycle	Nominal Battery Capacity (kWh)	Usable Battery Capacity (kWh)	Range (miles)	Energy Consumption (kWh/mile)
Drive Cycle 1	105.51	90.74	277.01	0.3276
Drive Cycle 2	105.51	90.74	304.81	0.2977

The results show that Drive Cycle 2 provides both more electric range and less energy consumption. Particularly, Drive Cycle 2 achieves an electric range of 304.81 miles,

surpassing Drive Cycle 1's electric range by 27.80 miles. Similarly, the energy consumed is also lower, being 0.2977 kWh/mile versus 0.3276 kWh/mile in Drive Cycle 1. It implies that Drive Cycle 2 is more energy-efficient than Drive Cycle 1. The reason behind this is most likely to be the smoothness of the speed profile of Drive Cycle 2, which requires little acceleration. As a result, the total electrical energy consumed will be low.

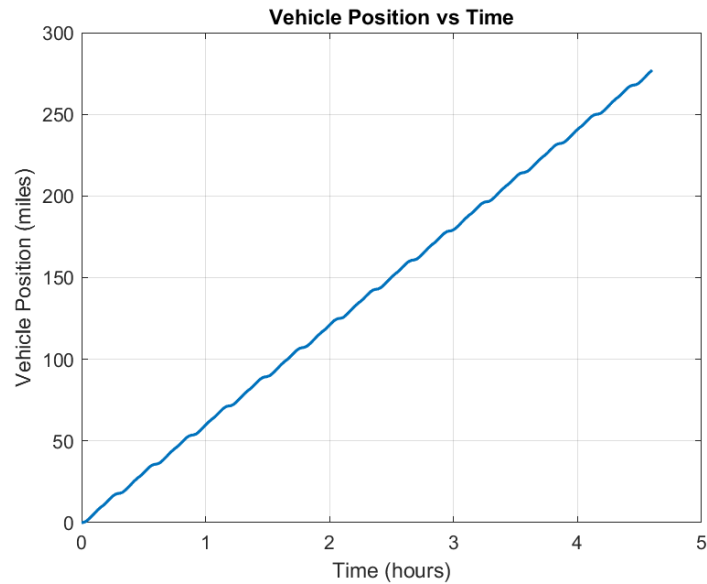


Figure 3 Range in miles scope/output for Drive Cycle 1 at $\text{regenRate} = 0.25$

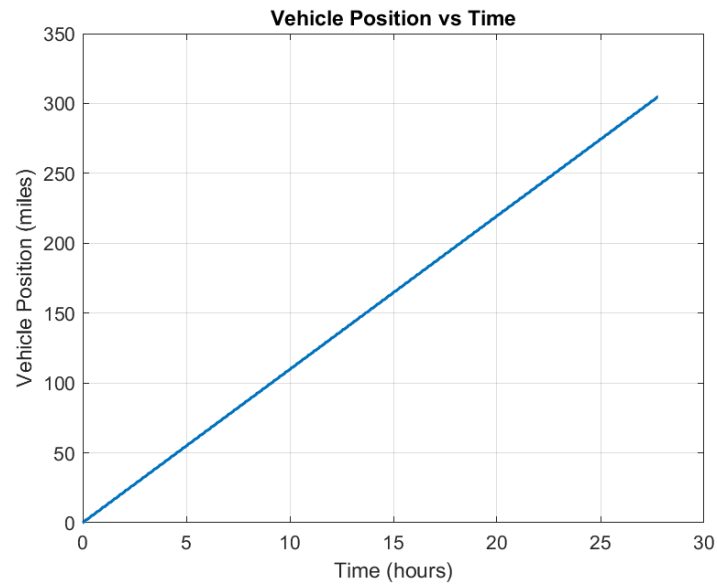


Figure 4 Range in miles scope/output for Drive Cycle 2 at $\text{regenRate} = 0.25$

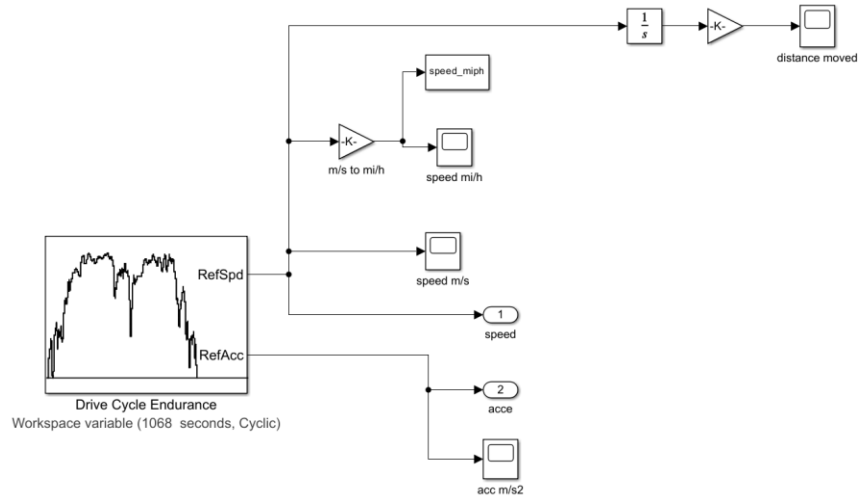


Figure 5 Scope or model screenshot showing speed-to-range integration method

Question C2: Re-run the simulation with modified regeneration coefficient

For Question C2, the regeneration coefficient was increased from the default value of **0.25** to **0.65**, as required by the assignment. The model was then re-run independently for both driving cycles using the same vehicle parameters and battery data. The updated results are shown in Table 2.

Table 2 Electric range and energy consumption results for regenRate = 0.65.

Driving Cycle	Nominal Battery Capacity (kWh)	Usable Battery Capacity (kWh)	Range (miles)	Energy Consumption (kWh/mile)
Drive Cycle 1	105.51	90.74	291.08	0.3117
Drive Cycle 2	105.51	90.74	304.81	0.2977

To assess the impact of changing the regenerative braking coefficient, the obtained results were contrasted with those acquired in the baseline experiment. Under Drive Cycle 1, an increase in the regeneration coefficient raised the electric range to 291.08 miles from 277.01 miles, which corresponds to an increment of 14.07 miles or 5.08%. At the same time, energy consumption decreased to 0.3117 kWh/mile from 0.3276 kWh/mile, a difference of approximately 4.85%. These data suggest that an increased regeneration coefficient provides substantial benefits under Drive Cycle 1 conditions.

In case of Drive Cycle 2, both the electric range and energy consumption remained unaltered at 304.81 miles and 0.2977 kWh/mile correspondingly. Thus, an increase in the regeneration coefficient did not provide any benefits in terms of efficiency.

The reason for the difference between the two drive cycles is connected to their driving profile. Specifically, Drive Cycle 1 is characterized by the presence of numerous and powerful decelerations, during which energy can be recovered and stored as an increase in the amount of charge in the batteries due to a higher regeneration coefficient. This, in turn, increases the efficiency and, therefore, the range. On the contrary, Drive Cycle 2 probably does not feature sufficient braking events at a regenerative brake coefficient of 0.25; as a result, there is no room for improvements with the increase of the coefficient.

Thus, one may note that regenerative braking can help achieve better performance; however, it depends on various factors. Increasing the regenerative braking coefficient does not necessarily mean that the benefits will occur. Rather, it is dependent on the drive cycle itself because it determines whether there will be sufficient deceleration opportunities or not. Therefore, regenerative braking provides more benefits for vehicles operating in urban and transitional conditions. It must be noted, however, that regenerative braking alone cannot serve as a solution to range extension since there are still some losses connected to, among others, aerodynamics and drivetrain.

Overall, Drive Cycle 1 benefits most from the higher regeneration coefficient, while Drive Cycle 2 shows no measurable benefit. This confirms that the effectiveness of regenerative braking depends strongly on the operating profile of the vehicle.

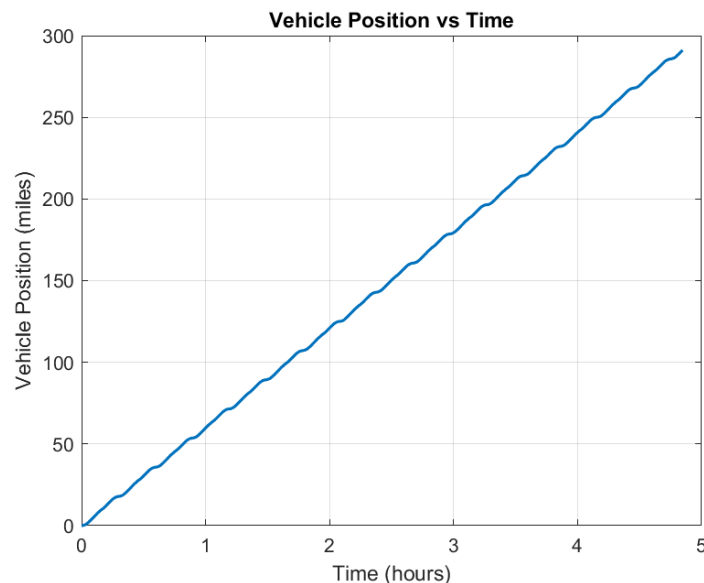


Figure 6 Range in miles scope/output for Drive Cycle 1 at $\text{regenRate} = 0.65$

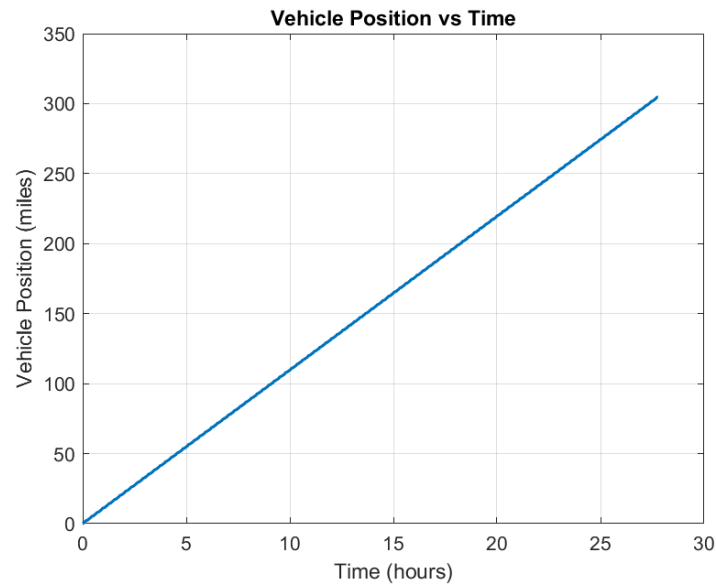


Figure 7 : Range in miles scope/output for Drive Cycle 2 at regenRate = 0.65

Conclusion

In this experiment, the electricity power demand, energy consumption, and electric range of an electric vehicle model implemented using the MATLAB/Simulink software package were investigated under two different driving conditions. After setting the specific values of the mass and battery size of the automobile, the Simulink model operated properly for both drive cycles. It can be seen from the analysis of the power demand curves that Drive Cycle 1 is less steady and more dynamic with high power fluctuation compared to Drive Cycle 2. Initial simulation output shows that Drive Cycle 2 provides more electric range and consumes less energy compared to Drive Cycle 1. However, after raising the regenerative brake ratio, there is no significant difference for Drive Cycle 2 but a slight increase in electric range in Drive Cycle 1 with a percentage value of about 5.08%. This indicates that regenerative braking proves most effective when the driving pattern includes many deceleration periods.

References

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