

MATLAB Simulation of Impact of Different Vehicle Parameters on Electric Vehicle Range

Aditya Nigam, Y. K. Bhatshvar

Abstract: India has been a late market for automobiles; passenger cars were a luxury for the general Indian population until the last two decades. This has caused a rapid increase in the number of automobiles in India is the rise in the amount of pollutants and other harmful gases and the continuous and ever going quest to obtain the fossil fuels required to fulfil the need for the people and their automobiles. This paper mainly deals with the range simulation using MATLAB which is required for the retrofitting of normal vehicles to reduce their carbon footprint and fossil fuel consumption to hybrid or purely electrical vehicles which would be affordable and familiar in use to an average person and how different parameters can cause a variation in range of the electric vehicle. This paper deals how parameters like battery type, rolling resistance, drag coefficient, frontal area etc. affect the overall driving range of an electric vehicle.

Index Terms: Range simulation, Weight of vehicle, Frontal area, power consumption, Transmission efficiency, rolling resistance.

I. INTRODUCTION

Electric vehicles are a promising alternative to vehicles powered by fossil fuels due to their cleaner energy emission. A discussion between the various stakeholders, including Government, industry, and academia, was initiated which could revolutionize the automobile sector in India and the world. But, as it is known, the hybrid and electrical vehicles are not available easily and are expensive in case of mass-production due to various different components which have to be imported from various suppliers and countries which cause the cost of the vehicle to be expensive for an average human being. Automobile Companies like General Motors, Lotus, Tata Motors, Tesla, Mahindra, Hero Electric etc. have been developing automobiles equipped with technologies to make them electrical but they main problem faced is concerned with the overall driving range of the vehicle due to battery technology currently being used, number of onboard electrical systems being used, type of tires etc. The weight of body, engine, and dimensions are changed to determine the performance of the vehicle if it is converted to hybrid or purely electrical.

The battery size, weight, charge, distance covered/battery charge are altered to obtain the average, and mileage as was produced by the petrol or the diesel engine. Many institutes and companies have been researching and trying to develop various technological solutions in case of retrofitting so that. The hybrid and electrical concepts can be used in the existing automobiles the customer already has and that too in a cheap and inexpensive manner. Retrofitting involves changing and adding few components to the automobile which would cause it to not remain completely dependent on fossil fuels for the purpose of operation.

II. SYSTEM ASSUMPTIONS

1. Is the vehicle required for high speed motorway driving, or is it simply for delivering people or loads about town at low speeds?
2. Vehicle needs to be protected against corrosion, the environment in which the vehicle is likely to be used needs defining.
3. The main areas which need specifying for an electric vehicle are range, speed, acceleration, type of use

The other assumptions being made in this case are based on considering the various reference vehicles and taking parameters such as mass, frontal area drag coefficient, gear ratio, regenerative braking ratio, Transmission efficiency, copper losses, iron losses, wind losses, motor losses, and power consumed by onboard electrical systems etc.

III. PROCESS EMPLOYED

As it is widely discussed, the major flaw with the electric vehicle technology is that the battery pack technology currently being used is not able to provide a decent driving range value which makes the electric vehicles impractical. The batteries being used currently take a very long time to charge and discharge very quickly which may cause the driver to be stuck midway between 2 charging stations which have not become very popular or practical either. Due to these problems the range of the vehicle is one of the major factor why these vehicles are expensive and not at all popular in the current consumers market. To make these vehicles practical a driver has to take utmost care while driving to obtain the maximum driving range from the vehicle. For this he has to monitor the amount of baggage in the vehicle, type of tires being used in the vehicle, frontal area of the vehicle, drag coefficient of the vehicle, number of accessories in the vehicles (Example: Mobile chargers, powerful sound systems etc.), number of onboard electrical systems (Example: Satellite navigation, lights, AC,

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* Correspondence Author

Aditya Nigam, Ashoka Society Arera Colony, Bhopal (M.P), India.

Y. K. Bhatshvar, Ashoka Society Arera Colony, Bhopal (M.P), India.

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Heater, Heated seats, Radio etc.) and make sure that all the components are working perfectly and there is no form of excessive resistance being produced or any electrical components is unnecessarily drawing power from the battery pack which could affect the range of the vehicle.

For this research a generalized simulation model using various reference vehicle models is created in MATLAB in which their range can be calculated keeping in mind various different parameters such as weight of the vehicle (Total weight = Curb weight of the vehicle + Weight of the onboard passengers + Weight of the luggage), Rolling resistance of wheels of different makes and companies, Frontal area of the vehicle, drag coefficient of the vehicles, onboard electronic systems etc. In this MATLAB simulation the variation in range is being calculated by changing only 1 parameter at a time while keeping all others as constant. The graphs produced show how a small variation in any one of the parameter can cause a significant effect on the overall driving range and how different parameter would have to be altered to compensate to achieve the desired range from an electric vehicle. For this research paper various types of vehicle models such as hatchback, Mid-size car, SUV, roadster, 5-door electric luxury sedan, hybrid electric vehicle.

Their required data is considered as:

1. Model 1 (Hatchback)

- i) Weight- 830kg
- ii) Dimensions- 3280 x 1514 x 1560 mm
- iii) Range – 140km
- iv) Battery- 210Ah lithium ion battery, 48V, requires 8hr of charging
- v) Motor- 25HP 3 phase induction motor (30kW@3500 rpm, 91Nm torque@2500rpm)
- vi) Total- 25HP@3750rpm, 53.9Nm@3400rpm
- vii) Performance- 85km/h, 0-100= 95s

2. Model 2 (Mid-size car)

- i) Weight- 1634 kg
- ii) Dimensions= L*B*H = 190 x 71.7 x 58 inches
- iii) Engine- 2.5l, 4 cylinder (156 HP @ 570 rpm, torque=156 @ 4500rpm)
- iv) Motor- Permanent magnet AC synchronous motor (10 kW, Torque= 199lbft @ 1500 rpm), (Overall= Motor+ engine = 200hp)
- v) Battery- Nickel metal hydride (204 cells, 6.5Ah)
- vi) Drag coefficient= 0.27
- vii) Range= 680 miles
- viii) Fuel capacity= 64L
- ix) Performance = 0-100 = 7.8s, quarter mile drag= 16s@86mph

3. Model 3 (SUV)

- i) Weight- 2319 kg
- ii) Dimension- 4950 x 1923 x 1776 mm
- iii) Fuel capacity –71L
- iv) Engine – 2.0L, 4 cylinder twin turbocharged (320HP @ 5700 rpm, Torque- 400Nm @ 2200-5400 rpm)
- v) Drag coefficient- 0.29
- vi) Battery- 9.2 kWh lithium ion, range- >43km, 2-4hr charging time

- vii) Motor-87HP@700 rpm AC motor, torque- 240Nm@3000rpm
- viii) Siemens motor- SIVETEC3601 motor (power=60kW, torque= 240Nm, max. rpm= 13000rpm, peak current= 410A, efficiency= 90%)
- ix) Also has a 46HP motor between engine and rear mounted motor
- x) Total= 400HP and 472lbft
- xi) Mileage- 53mpg

4. Model 4 (Roadster)

- i) Weight- 1305kg
- ii) Dimensions- 3946 x 1873 x 1127 mm
- iii) Range- 393km
- iv) Drag coefficient- 0.36
- v) Rolling resistance- 0.011
- vi) Mileage- 120MPGe
- vii) Battery- lithium ion battery pack (6831 cells), uses 135Wh/km, 88% efficiency, 53kWh, capacity- 160Ah
- viii) Motor- 3 phase 4 pole AC induction motor (288HP (215kW), torque=400Nm@1100rpm 400Nm@1100rpm)

5. Model 5 (5- door luxury sedan)

- i) Weight- 2239kg
- ii) Dimensions- 4976 x 1964 x 1435 mm
- iii) Range- 426km
- iv) Drag coefficient- 0.24
- v) Battery- lithium ion 100kWh (360MJ), (weight- 540kg, 7104 cells in 16 modules)
- vi) Regenerative braking- 60kW
- vii) Motors- 3 phase AC induction motors (front+ rear motor= 762HP(568kW), Torque= 931Nm), (rear motor 416HP (310kW), torque= 600Nm)
- viii) Performance- top speed- 155mph, 0-60 in 2.8s
- ix) Front and rear has no linkage and power distribution is done electronically
- x) Software update can add almost 31km

6. Model 6 (Complete hybrid electric vehicle)

- i) Weight- 1394kg
- ii) Tank- 43L
- iii) Range- 640miles(total), 25 miles (EV)
- iv) Dimensions- 182.9 x 69.3 x 57.9 inches
- v) Engine- 1.8L 4 cylinders (Power- 95HP@5200rpm almost 69.92kW, Torque- 142Nm@3600rpm, efficiency- 60%)
- vi) Battery- Lithium ion battery (8.8kWh, 95cells, 265 pounds, 5-6hr charging time)
- vii) Motor-generator- 71hp (53kW), torque= 163Nm
- viii) Coefficient drag- 0.24
- ix) Consists of solar panels to charge 12V&8.8kWh (Power= 150W)
- x) Total- 121HP

In case of range simulation using rolling resistance of the tires of the various reference vehicles the data that is taken into consideration is:

- 1) Bridgestone B381 = 0.00615

- 2) Continental Ecocontact 5 205/55R16= 0.00770
- 3) Michelin Tiger Paw AWP 185/70R14 = 0.00875
- 4) Goodyear Integrity 185/70R14 = 0.00968
- 5) Dunlop Pilot Sport M2 205/55R16= 0.01020
- 6) Michelin Pilot Sport 205/55R16= 0.01328

Now considering each factor for each of the reference model vehicles, the variation in the driving range of the vehicle can be simulated.

IV. IMPLEMENTATION

i. Mass

The weight of the vehicles considered for this simulation process is the sum of the curb weight of the vehicle and the weight of the passengers and the weight of the baggage that could be kept in the boot of the vehicle. In this case the parameters such as frontal area, rolling resistance, drag coefficient, gear ratio, transmission efficiency, regenerative braking efficiency, type of battery (in this case lithium ion is considered with 250 cells and 12V, 60Ah batteries) and similar average power consumption by accessories etc. are taken same while only weights of the vehicles are varied to determine how it effects the overall driving range

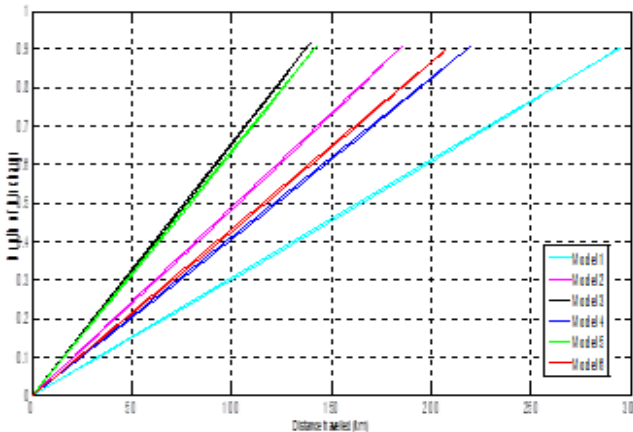


Figure 1: Graph Showing Effect of VEHICLE’s Curb Weight on the Driving Range

ii. Rolling Resistance

Rolling resistance, sometimes called rolling friction or rolling drag, is the force resisting the motion when a body (such as a ball, tire, or wheel) rolls on a surface. In case of electric vehicles low rolling resistance tires are preferred because they minimize wasted energy as a tire rolls, thereby decreasing required rolling effort — and in the case of automotive applications, improving vehicle fuel efficiency.

The graph shows how the range of the vehicle would vary based on the rolling resistance values of tires produced by different companies such as Bridgestone, Michelin, Dunlop, Continental, Goodyear.

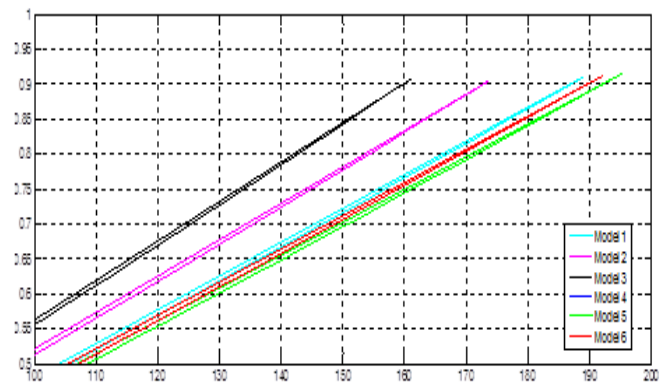


Figure 2: Graph showing effect of rolling resistance of tires on vehicle’s driving range

In this case the parameters such as weight, frontal area, drag coefficient, gear ratio, transmission efficiency, regenerative braking efficiency, type of battery (in this case lithium ion is considered with 250 cells and 12V, 60Ah batteries) and similar average power consumption by accessories etc. are taken as constant while varying only the coefficient of rolling of the tires to determine how it effects the overall driving range. In the case of rolling resistance the variation in the overall driving range of the vehicle varies in very small values that is the only changes that occur is in a matter of some meters which do not make a large or significant difference to the driving range.

iii. Frontal Area:

The frontal area of the vehicle is one of the major reason of reduced range in an electric vehicle. It is the area where a car hits the air head – on. The total resistance offered by the vehicle is the product of frontal area and drag coefficient. The force exerted by air on anybody moving through it is called Aerodynamic Drag.

Aerodynamic Drag = Frontal area of the vehicle X drag coefficient

The plot below how small but significant difference there is on the driving range of the vehicle based on frontal area of the vehicle.

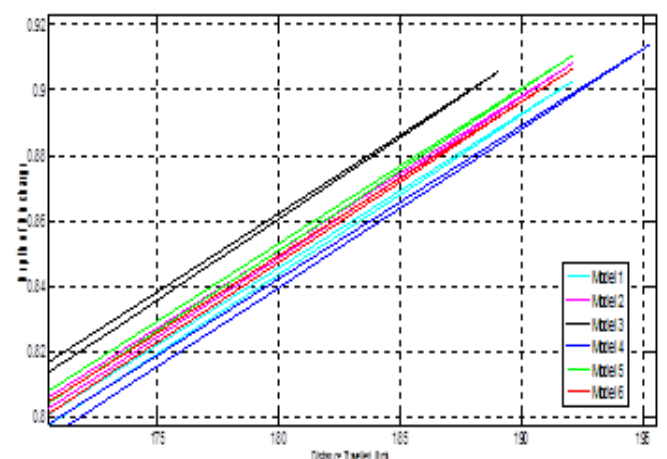


Figure 3: Plot showing effect of frontal area on range

The above plot shows how the frontal area of cars differ and how it affects the driving range of the electric vehicle. It shows that the Model 3 has the largest frontal area as a SUV has the

most height and width and the Model 4 has the least frontal area.

The above plot shows the effect on driving range by the aerodynamic drag on the vehicles body. It shows how less difference between Tesla Model X and the Mahindra e2o.

iv. Transmission Efficiency

The transmission in a car (or any motorized wheeled vehicle) is a system of gears that literally “transmits” the power generated by the engine to the wheels that drive the vehicle forward. The ratio of the power received over a transmission path to the power transmitted. The transmission efficiency are usually tested on purpose built rigs or a chassis dynamometer. For this the wheel power and engine output data is considered for the calculation.

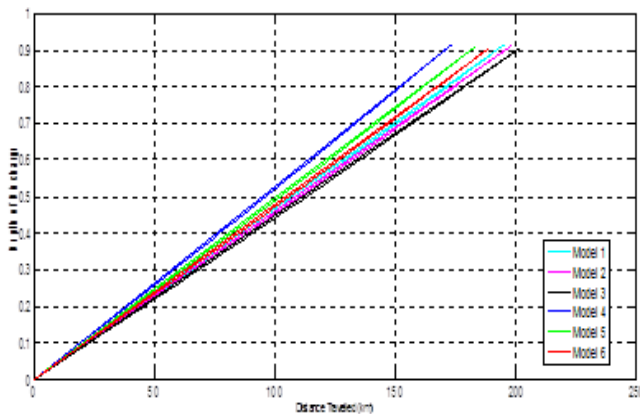


Fig. 4: The above plots shows how the transmission efficiency changes from SUVs like Volvo XC90 to the Mahindra e2o

v. Power consumption by accessories

The plots given below show how the power consumed by the onboard electrical systems and accessories affects the overall driving range of an electrical vehicle. For these plots the basic consideration is done by assuming that no electrical Systems are ON and then the plots are produced by turning ON one system at a time to see the effect of power consumption on the overall driving range.

The electrical systems selected are:

1. High powered headlights
2. Mobile Phone Charger
3. Satellite Navigation system
4. Heated seats
5. Music System
6. Music system with subwoofers and amplifiers
7. Air conditioning

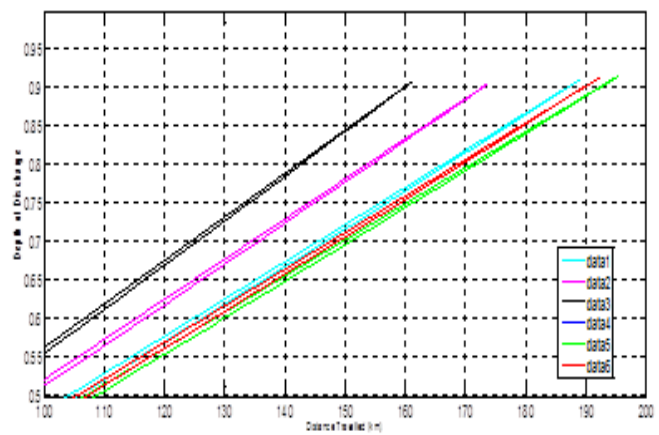


Fig. 5: Various plots designate the driving range of the vehicle

- 1) Data1- Basic (when no electrical system is drawing power from the battery except the driving motor)
- 2) Data2- Basic + Powerful headlights
- 3) Data3- Basic + Powerful headlights + heated seats + satellite navigation
- 4) Data4- Basic + Powerful headlights + heated seats + satellite navigation + mobile charger
- 5) Data5- Basic + Powerful headlights + heated seats + satellite navigation + mobile charger+ radio with subwoofer and amplifier
- 6) Data6- Basic + Powerful headlights + heated seats + satellite navigation + mobile charger+ radio with subwoofer and amplifier + Air Conditioning

The Above graph shows how much the range is affected when no electrical system is operational in the car (red) and how it changes when headlights are switched On (blue), when headlights and heated seats and satellite navigation is ON (black), when headlights, heated seats, satellite navigation and the car charger are being used continuously through the journey (Purple).

The above graph shows how much difference the power consumption by music system with subwoofer and amplifier and air conditioning makes for an electric vehicle.

(The air conditioning reduces the range the most as it requires almost 3000W power which it draws directly from the belt in the ICE based vehicle which would be a major problem in an electric car if it is operating continuously.)

V. CONCLUSION

This research paper shows how to obtain the maximum possible driving range from a retrofitted vehicles whose main electrical configuration is nearly same to the considered reference models and how it can be made nearly at par with the range provided by an internal combustion engine and is practical for an average customer. It shows the effect of different parameters such as weight of the vehicle, rolling resistance of tires, aerodynamic drag, frontal area, transmission efficiency, power consumption of accessories have on the overall driving range of an electric vehicle. The simulations done using MATLAB help in the process of retrofitting of an ICE based vehicle to determine the best combination of components to be used in a vehicle so that

overall cost of the retrofitted vehicle is less than that of a factory produced electric vehicle but can perform better than it. The paper helps in determining the combination of parts which would help compensate the driving range of a vehicle for an irreplaceable part which affects the driving range in a major way.

APPENDIX

```
%TESLA ROADSTER
SFUDS; % Get the velocity values, they
are in % an array V.
N=length(V); % Find out how many
readings %Divide all velocities by 3.6,
to convert to m/sec
V=V./3.6;
mass = 1540 ; % Vehicle mass+ two 70 kg
passengers.
area = 1.8; % Frontal area in square
metres
Cd = 0.24; % Drag coefficient
Gratio = 37; % Gearing ratio, = G/r
G_eff = 0.95; % Transmission efficiency
Regen_ratio = 0.5; % This sets the
proportion of the % braking that is done
regeneratively % using the motor.
bat_type='Liion'; % Lead acid battery
NoCells=250; % 26 of 6 cell (12 Volt)
batteries.
Capacity=60; % 60 Ah batteries
k=1.12; % Peukert coefficient, typical
for good lead acid
Pac=500; % Average power of accessories
kc=0.3; % For copper losses
ki=0.01; % For iron losses
kw=0.000005; % For windage losses
ConL=600; % For constant electronics
losses
urr=0.00615;
Frr=0.00615 * mass * 9.8; % Equation 7.1
Rin= (0.022/Capacity)*NoCells; % Int.
res, Equ. 2.2
Rin = Rin + 0.05; % Add a little to make
allowance for % connecting leads.
PeuCap= ((Capacity/10)^k)*10;
DoD_end = zeros(1,N);
CR_end = zeros(1,N);
D_end = zeros(1,N);
DoD=zeros(1,N); % Depth of discharge, as
in Chap. 2
CR=zeros(1,N); % Charge removed from
battery, Peukert % corrected, as in Chap
2.
D=zeros(1,N); % Record of distance
traveled in km.
CY=1;
DD=0;
while DD < 0.9
    one_cycle;
    %fprintf('one_cycle');
    DoD_end(CY) = DoD(N);
    CR_end(CY) = CR(N);
    D_end(CY) = D(N);
    DoD(1)=DoD(N);
    CR(1)=CR(N);
```

```
D(1)=D(N);
DD=DoD_end(CY); % Update state of
discharge %END OF ONE CYCLE
CY = CY +1;
hold on
plot(D_end,DoD_end,'b');
end;
save Roadster
% hold on
% plot(D_end,DoD_end,'b');
% % % set(gca,'XTickLabel',[0, 20, 40,
60, 80, 100, 120, 140, 160, 180, 200]
);
hold on
% ylabel('Depth of discharge');
% xlabel('Distance traveled/km');
%
legend('ROADSTER','Location','southeast'
);

clear all;
%TESLA MODEL S
SFUDS; % Get the velocity values, they
are in % an array V.
N=length(V); % Find out how many
readings %Divide all velocities by 3.6,
to convert to m/sec
V=V./3.6;
mass = 1540 ; % Vehicle mass+ two 70 kg
passengers.
area = 1.8; % Frontal area in square
metres
Cd = 0.24; % Drag coefficient
Gratio = 37; % Gearing ratio, = G/r
G_eff = 0.95; % Transmission efficiency
Regen_ratio = 0.5; % This sets the
proportion of the % braking that is done
regeneratively % using the motor.
bat_type='Liion'; % Lead acid battery
NoCells=250; % 26 of 6 cell (12 Volt)
batteries.
Capacity=60; % 60 Ah batteries
k=1.12; % Peukert coefficient, typical
for good lead acid
Pac=580; % Average power of accessories
kc=0.3; % For copper losses
ki=0.01; % For iron losses
kw=0.000005; % For windage losses
ConL=600; % For constant electronics
losses
urr=0.00615;
Frr=0.00615 * mass * 9.8; % Equation 7.1
Rin= (0.022/Capacity)*NoCells; % Int.
res, Equ. 2.2
Rin = Rin + 0.05; % Add a little to make
allowance for % connecting leads.
PeuCap= ((Capacity/10)^k)*10;
DoD_end = zeros(1,N);
CR_end = zeros(1,N);
D_end = zeros(1,N);
DoD=zeros(1,N); % Depth of discharge, as
in Chap. 2
CR=zeros(1,N); %
Charge removed from
battery, Peukert %
```

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```

corrected, as in Chap 2.
D=zeros(1,N); % Record of distance
traveled in km.
CY=1;
DD=0;
while DD < 0.9
    one_cycle;
    %fprintf('one_cycle');
    DoD_end(CY) = DoD(N);
    CR_end(CY) = CR(N);
    D_end(CY) = D(N);
    DoD(1)=DoD(N);
    CR(1)=CR(N);
    D(1)=D(N);
    DD=DoD_end(CY); % Update state of
discharge %END OF ONE CYCLE
    CY = CY +1;
    hold on
    plot(D_end,DoD_end,'g');
end;
save S
% hold on
% plot(D_end,DoD_end,'g');
% % % set(gca,'XTickLabel',[0, 20, 40,
60, 80, 100, 120, 140, 160, 180, 200]
);
hold on

% ylabel('Depth of discharge');
% xlabel('Distance traveled/km');
% legend('ROADSTER','Model
S','Location','southeast');
clear all;
%TOYOTA PRIUS PRIME
SFUDS; % Get the velocity values, they
are in % an array V.
N=length(V); % Find out how many
readings %Divide all velocities by 3.6,
to convert to m/sec
V=V./3.6;
mass = 1540 ; % Vehicle mass+ two 70 kg
passengers.
area = 1.8; % Frontal area in square
metres
Cd = 0.24; % Drag coefficient
Gratio = 37; % Gearing ratio, = G/r
G_eff = 0.95; % Transmission efficiency
Regen_ratio = 0.5; % This sets the
proportion of the % braking that is done
regeneratively % using the motor.
bat_type='Liion'; % Lead acid battery
NoCells=250; % 26 of 6 cell (12 Volt)
batteries.
Capacity=60; % 60 Ah batteries
k=1.12; % Peukert coefficient, typical
for good lead acid
Pac=700; % Average power of accessories
kc=0.3; % For copper losses
ki=0.01; % For iron losses
kw=0.000005; % For windage losses
ConL=600; % For constant electronics
losses
urr=0.00615;

Frr=0.00615 * mass * 9.8; % Equation
7.1
Rin= (0.022/Capacity)*NoCells; % Int.
res, Equ. 2.2
Rin = Rin + 0.05; % Add a little to
make allowance for % connecting leads.
PeuCap= ((Capacity/10)^k)*10;
DoD_end = zeros(1,N);
CR_end = zeros(1,N);
D_end = zeros(1,N);
DoD=zeros(1,N); % Depth of discharge,
as in Chap. 2
CR=zeros(1,N); % Charge removed from
battery, Peukert % corrected, as in Chap
2.
D=zeros(1,N); % Record of distance
traveled in km.
CY=1;
DD=0;
while DD < 0.9
    one_cycle;
    %fprintf('one_cycle');
    DoD_end(CY) = DoD(N);
    CR_end(CY) = CR(N);
    D_end(CY) = D(N);
    DoD(1)=DoD(N);
    CR(1)=CR(N);
    D(1)=D(N);
    DD=DoD_end(CY); % Update state of
discharge %END OF ONE CYCLE
    CY = CY +1;
    hold on
    plot(D_end,DoD_end,'r');
end;
save PRIME
% hold on
% % plot(D_end,DoD_end,'r');
% % % % set(gca,'XTickLabel',[0, 20, 40,
60, 80, 100, 120, 140, 160, 180, 200]
);
hold on
% ylabel('Depth of discharge');
% % xlabel('Distance traveled/km');
% % legend('ROADSTER','Model S','PRIUS
PRIME','Location','southeast');

clear all;
%MAHINDRA e2o
SFUDS; % Get the velocity values, they
are in % an array V.
N=length(V); % Find out how many
readings %Divide all velocities by 3.6,
to convert to m/sec
V=V./3.6;
mass = 1540 ; % Vehicle mass+ two 70 kg
passengers.
area = 1.8; % Frontal area in square
metres
Cd = 0.24; % Drag coefficient
Gratio = 37; % Gearing ratio, = G/r
G_eff = 0.95; % Transmission efficiency
Regen_ratio = 0.5; % This
sets the proportion of the % braking that
is done

```

```

regeneratively % using the motor.
bat_type='Liion'; % Lead acid battery
NoCells=250; % 26 of 6 cell (12 Volt)
batteries.
Capacity=60; % 60 Ah batteries
k=1.12; % Peukert coefficient, typical
for good lead acid
Pac=760; % Average power of accessories
kc=0.3; % For copper losses
ki=0.01; % For iron losses
kw=0.000005; % For windage losses
ConL=600; % For constant electronics
losses
urr=0.00615;
Frr=0.00615 * mass * 9.8; % Equation
7.1
Rin= (0.022/Capacity)*NoCells; % Int.
res, Equ. 2.2
Rin = Rin + 0.05; % Add a little to
make allowance for % connecting leads.
PeuCap= ((Capacity/10)^k)*10;
DoD_end = zeros(1,N);
CR_end = zeros(1,N);
D_end = zeros(1,N);
DoD=zeros(1,N); % Depth of discharge,
as in Chap. 2
CR=zeros(1,N); % Charge removed from
battery, Peukert % corrected, as in Chap
2.

D=zeros(1,N); % Record of distance
traveled in km.
CY=1;
DD=0;
while DD < 0.9
    one_cycle;
%     %fprintf('one_cycle');
DoD_end(CY) = DoD(N);
CR_end(CY) = CR(N);
D_end(CY) = D(N);
DoD(1)=DoD(N);
CR(1)=CR(N);
D(1)=D(N);
DD=DoD_end(CY); % Update state of
discharge %END OF ONE CYCLE
CY = CY +1;
hold on
plot(D_end,DoD_end,'c');
end;
save e2o
% hold on
% % plot(D_end,DoD_end,'c');
% % % % set(gca,'XTickLabel',[0, 20, 40,
60, 80, 100, 120, 140, 160, 180, 200]
);
hold on
% % ylabel('Depth of discharge');
% % xlabel('Distance traveled/km');
% % legend('ROADSTER','Model S','PRIUS
PRIME','e2o','Location','southeast');

clear all;
%TOYOTA CAMRY

```

```

SFUDS; % Get the velocity values, they
are in % an array V.
N=length(V); % Find out how many
readings %Divide all velocities by 3.6,
to convert to m/sec
V=V./3.6;
mass = 1540 ; % Vehicle mass+ two 70 kg
passengers.
area = 1.8; % Frontal area in square
metres
Cd = 0.24; % Drag coefficient
Gratio = 37; % Gearing ratio, = G/r
G_eff = 0.95; % Transmission efficiency
Regen_ratio = 0.5; % This sets the
proportion of the % braking that is done
regeneratively % using the motor.
bat_type='Liion'; % Lead acid battery
NoCells=250; % 26 of 6 cell (12 Volt)
batteries.
Capacity=60; % 60 Ah batteries
k=1.12; % Peukert coefficient, typical
for good lead acid
Pac=1100; % Average power of
accessories
kc=0.3; % For copper losses
ki=0.01; % For iron losses
kw=0.000005; % For windage losses
ConL=600; % For constant electronics
losses
urr=0.00615;
Frr=0.00615 * mass * 9.8; % Equation
7.1
Rin= (0.022/Capacity)*NoCells; % Int.
res, Equ. 2.2
Rin = Rin + 0.05; % Add a little to
make allowance for % connecting leads.
PeuCap= ((Capacity/10)^k)*10;
DoD_end = zeros(1,N);
CR_end = zeros(1,N);
D_end = zeros(1,N);
DoD=zeros(1,N); % Depth of discharge,
as in Chap. 2
CR=zeros(1,N); % Charge removed from
battery, Peukert % corrected, as in Chap
2.
D=zeros(1,N); % Record of distance
traveled in km.
CY=1;
DD=0;
while DD < 0.9
    one_cycle;
%     %fprintf('one_cycle');
DoD_end(CY) = DoD(N);
CR_end(CY) = CR(N);
D_end(CY) = D(N);
DoD(1)=DoD(N);
CR(1)=CR(N);
D(1)=D(N);
DD=DoD_end(CY); % Update state of
discharge %END OF ONE CYCLE
CY = CY +1;
hold on

```

MATLAB Simulation of Impact of Different Vehicle Parameters on Electric Vehicle Range

```

plot(D_end,DoD_end,'m');
end;
save CAMRY
%% hold on
%% plot(D_end,DoD_end,'m');
%% %% set(gca,'XTickLabel',[0, 20, 40,
60, 80, 100, 120, 140, 160, 180, 200]
);
hold on
%% ylabel('Depth of discharge');
%% xlabel('Distance traveled/km');
%% legend('ROADSTER','Model S','PRIUS
PRIME','e2o','CAMRY','Location','southea
st');

clear all;
%VOLVO XC90
SFUDS; % Get the velocity values, they
are in % an array V.
N=length(V); % Find out how many
readings %Divide all velocities by 3.6,
to convert to m/sec
V=V./3.6;
mass = 1540 ; % Vehicle mass+ two 70 kg
passengers.
area = 1.8; % Frontal area in square
metres
Cd = 0.24; % Drag coefficient
Gratio = 37; % Gearing ratio, = G/r
G_eff = 0.95; % Transmission efficiency

Regen_ratio = 0.5; % This sets the
proportion of the % braking that is done
regeneratively % using the motor.
bat_type='Liion'; % Lead acid battery
NoCells=250; % 26 of 6 cell (12 Volt)
batteries.
Capacity=60; % 60 Ah batteries
k=1.12; % Peukert coefficient, typical
for good lead acid
Pac=3100; % Average power of
accessories
kc=0.3; % For copper losses
ki=0.01; % For iron losses
kw=0.000005; % For windage losses
ConL=600; % For constant electronics
losses
urr=0.00615;
Frr=0.00615 * mass * 9.8; % Equation
7.1
Rin= (0.022/Capacity)*NoCells; % Int.
res, Equ. 2.2
Rin = Rin + 0.05; % Add a little to
make allowance for % connecting leads.
PeuCap= ((Capacity/10)^k)*10;
DoD_end = zeros(1,N);
CR_end = zeros(1,N);
D_end = zeros(1,N);
DoD=zeros(1,N); % Depth of discharge,
as in Chap. 2

```

```

CR=zeros(1,N); % Charge removed from
battery, Peukert % corrected, as in Chap
2.
D=zeros(1,N); % Record of distance
traveled in km.
CY=1;
DD=0;
while DD < 0.9
    one_cycle;
    %% fprintf('one_cycle');
    DoD_end(CY) = DoD(N);
    CR_end(CY) = CR(N);
    D_end(CY) = D(N);
    DoD(1)=DoD(N);
    CR(1)=CR(N);
    D(1)=D(N);
    DD=DoD_end(CY); % Update state of
discharge %END OF ONE CYCLE
    CY = CY +1;
    hold on
    plot(D_end,DoD_end,'k');
end;
save XC90
%% hold on
%% plot(D_end,DoD_end,'k');
%% %% set(gca,'XTickLabel',[0, 20, 40,
60, 80, 100, 120, 140, 160, 180, 200]
);
hold on
grid on;
ylabel('Depth of discharge');
xlabel('Distance traveled/km');
legend('ROADSTER','Model S','PRIUS
PRIME','e2o','CAMRY','XC90')%, 'Location'
,'southeast');

```

The different plots are generated by varying the parameters one by one to simulate the effect of each parameter on the overall driving range.

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