Design and Comparative Analysis of Battery Electric vehicle

[1]B. Anil Kumar,[2]G. Jhansi Rani

[1*]PG Student, Department of Electrical Engineering, University College of Engineering,Osmania University, Hyderabad, Telangana, India.

[2]Assistant Professor, Department of Electrical Engineering, University College of Engineering,Osmania University, Hyderabad, Telangana, India.

Keywords:

Electric vehicle
Drive Cycle
PMDC Motor
State of Charge
Lithium-ion battery.

A B S T R A C T

The rapid improvement of technology in the vehicular industry brings new challenges to EV manufacturers to introduce high performance Electric vehicle models into the EV market. In this paper, the main focus is on evaluating the performance of two different electric vehicles by taking a drive cycle as input to the vehicle. Two EV's that are already existing in the market are taken for the performance analysis and Comparison. One is 2019 Tesla model 3 Standard range RWD and other is 2023 Tesla Model Y RWD. These two models are selected to determine and analyse their performance parameters like State of charge of the battery, Range and Speed with different drive cycles that are available in MATLAB/Simulink. For the Simulation and performance analysis of electric vehicle, MATLAB is the most widely used simulator for the researchers.

1. Introduction:

The concept of mobility is changing because of electric vehicles, or EVs. Fossil fuels play dominant role in the transport sector. Due to large demand of vehicles for transportation, the usage of fossil fuels has been increasing. When the fossil fuels are burned, CO_2 will be released into the atmosphere which leads to Global Warming i.e., increase of earth average surface temperature.[1] So, it is necessary to shift our focus to another alternative fuel to run the vehicle. Recently, World air quality report was released by IQ Air. It was a Swiss based air quality technology company. The report says that India is the third most air polluted country in the world out of 134 countries. Average PM2.5 Concentration is 54.4 μg/m^3. New Delhi is most polluted capital city in the world. PM2.5 indicates Particulate Matter includes microscopic harmful particles suspended in the air. The size of the particles is less than 2.5 μm in diameter. As the size of the particles decreases, the air becomes more toxic. As per IIT Kanpur study report, the major source contribution for air pollution in GHMC area include the following.

Table 1
Sources of air pollution in GHMC area

S. No	Source	Percentage in Air (%)
1	Road dust	30
2	Vehicle	17
3	SIA (secondary inorganic aerosols)	15
4	Biomass burning	10
5	C & D (Construction and demolition) waste	8
6	Municipal solid waste	7
7	Industrial	5

From the above table, it is observed that major source of air pollution is Road dust and the percentage of industrial waste that causing air pollution is 5%. Telangana Pollution Control board claims that the Concentrations of PM10 fell from 101 μg/m³ in 2019-20 to 83 μg/m³ in 2023-2024 up to current date in Hyderabad.

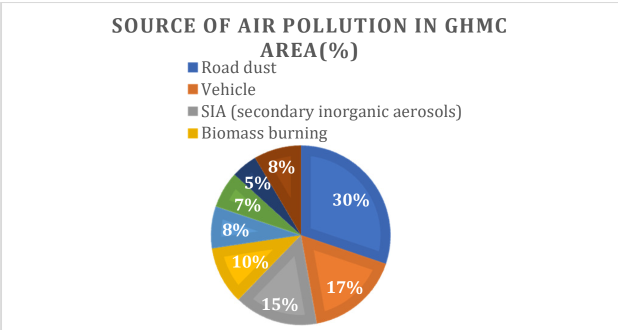


Fig. 1.1 Source Contribution of air pollution.

Electric vehicles becoming alternative to Conventional vehicles as they cause urban air pollution by emitting greenhouse gases into to the atmosphere. Another reason is depletion of fossil fuels such as petrol and diesel. In Electric vehicles, kinetic energy produced during braking is converted into electric energy and this energy can be stored. Thus, EV's are more efficient.

According to the Energy Policy Act of 1992, Electricity is considered as one of the alternative fuels. The sources of Electrical energy include solar energy, Wind Energy, nuclear energy. The concept of Electric vehicle is introduced into the market which uses electricity for its propulsion. Electric vehicles reduce greenhouse emissions, fuel costs and improves fuel economy.[2]

Because of the increased cost of fossil fuels i.e., petrol, diesel the demand for electric vehicle has also been increased. In the financial year 2023, around 13.6 million electric vehicles are sold all around the world. The numbers may increase in the next financial year.

In this Project, detailed approach to design an electric vehicle will be shown in MATLAB/SIMULINK. MATLAB software is used by many manufacturers to predict the performance of the electric vehicle under different environments. To design a complete EV model, there are different steps. It includes design of drive cycle, Driver controller, vehicle body, motor and motor controller.

By noting down the technical specifications of two different EV's from their brochures i.e., Tesla model 3 standard range RWD and Tesla Model Y RWD, the Simulink blocks in the MATLAB software can achieve almost accurate results. This project is also focused on Comparing the performances of two EV Models that are already existing in the market.

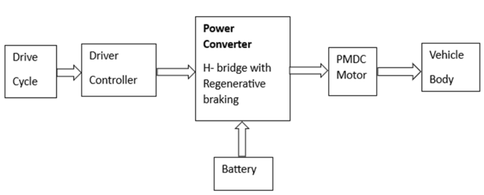


Fig. 1.2 Block diagram for EV design

2. Specifications and parameters used in EV design

For design and analysis, certain reference data is required. The simulation used in this study is based on the 2019 Tesla Model 3 Standard Range RWD & 2023 Tesla Model Y RWD specifications. [3]

Table 2

Specifications and Parameters used in this design

S. No	Parameter	Values		Units
		Tesla Model 3 RWD	Tesla Model Y RWD	
1	Manufacturer	Tesla	Tesla	-
2	Model year	2019	2023	-
3	Body type	Sedan	Sports Utility Vehicle	-
4	Drive Train	Rear Wheel Drive	Rear Wheel Drive	-
5	Full body mass(M)	1611	1909	kg
6	length	4.69	4.74	m
7	width	1.8	1.9	m
8	height	1.4	1.6	m
9	Frontal Area	2.5	2.9	m²
10	Drag Coefficient	0.23	0.24	-
11	Area of the Vehicle	8.28	8.93	m²
12	No. of wheels per axle	2	2	-
13	Gear ratio	9	9	-
14	Wheel size	235/45 R18	255/45 R19	-
15	Coefficient of rolling resistance	0.01	0.01	-
16	Air Density	1.25	1.25	-
17	Type of rechargeable battery	Lithium-ion	Lithium-ion	-
18	Battery Voltage	360	345	Volts
19	Battery Capacity	50	62	KWh
20	Motor Power	239	255	KW
21	Regenerative Braking	yes	yes	-
22	Motor Torque	420	420	N-m
23	Acceleration 0-100 KM	5.9	6.9	Seconds
24	Vehicle range per charge	354	430	Km

3. Creating EV design in Simulink

Connecting the various components together forms an electric car is the first step in the process. They consist of the Chassis, Battery systems, Drive controllers and Drive cycle, Motor, and Power Converter. The following figure shows the logical power flow diagram for the EV model.[4]

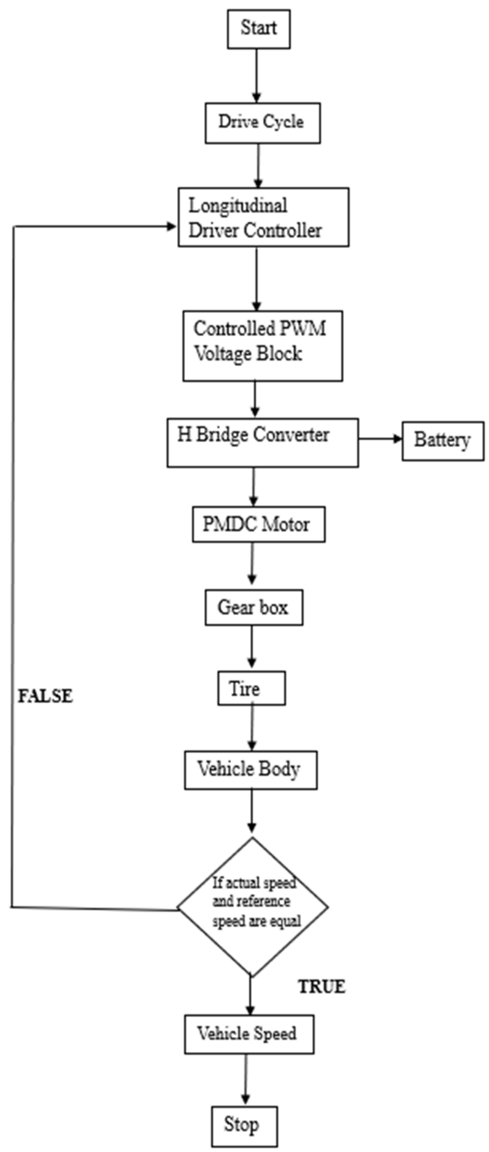


Fig. 3.1 Logical Flow diagram of EV model.

To design a complete EV, six main blocks are required. They are:

- Drive Cycle Setup.
- Longitudinal Driver.
- Design of Motor Controller.
- Battery Setup Design.
- Motor design.
- Design of vehicle body.

4. Drive cycle setup & longitudinal driver

In this chapter, brief description about drive cycle setup and longitudinal driver is explained.

Open the MATLAB software and SIMULINK file that appears on the top. Select the drive cycle block from MATLAB library. Design of EV starts with drive cycle setup. Drive cycle is the pre-defined input to the vehicle.

A flexible tool for simulating vehicle operation under various driving situations in MATLAB is the Drive Cycle block. A driving cycle is a set of data points that show a vehicle's speed as a function of time. The Drive Cycle block allows you to examine how vehicles or vehicle systems operate in various driving scenarios by simulating real-world conditions. A drive cycle simulates actual driving conditions and shows how a vehicle's speed, acceleration, and other characteristics change over time. Various countries and organizations create driving cycles to evaluate the efficiency of automobiles. [5] [6]

There different types of Drive cycles available in MATLAB/Simulink are FTP75, EUDC, Japanese 10 mode, Artemis Motorway etc. In this design, WLTP Class 1 drive cycle is used as predefined input to the vehicle.

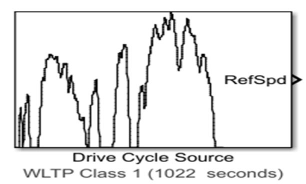


Fig. 4.1 WLTP Class 1 Drive Cycle

Select the Longitudinal Driver block from the MATLAB library. It compares the reference speed and vehicle speed. Longitudinal driver has inbuilt PI controller. Drive cycle is connected to it. Drive cycle source is the speed data. It should be converted into acceleration. Thus, longitudinal driver block is required.

A longitudinal speed-tracking controller is implemented through the Longitudinal Driver block. The block produces normalized accelerating and braking commands which range from 0 to 1 based on reference and feedback velocities. The block can be used to create the commands required to track a longitudinal driving cycle or to simulate a driver's dynamic response.

To establish reference tracking, PI control is employed. The vehicle's instance velocity at different points of time is represented by a driving cycle. Using a controller is supposed to provide control over the output velocity to track the input reference velocity. A longitudinal driver block is used for this. This block has 3 input ports and 3 output ports.

The driver compares actual speed and reference speed. If the error is positive i.e., if reference speed is greater than actual speed then driver presses the accelerator. If the error is negative i.e., if the actual speed greater than reference speed then driver press brake.

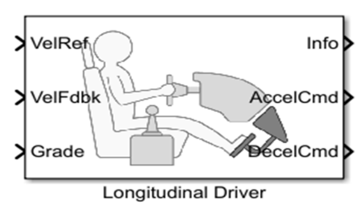


Fig. 4.2 Longitudinal Driver Block.

5. Design of motor controller

For a vehicle's propulsion, an electric motor is crucial. It needs to be managed more effectively. From the Simulink library, select the H-Bridge converter. Thus, it manages the motor and regenerates electric power when it decelerates. Regenerated power is stored in the battery. Longitudinal driver block can generate both acceleration command and deceleration command.

H-Bridge converter receives the signal from the Controlled PWM voltage block and vehicle moves. Similarly, it also receives deceleration signal so that the motor stops. Regenerative Braking process takes place when the motor speed slows down.[5] Here the current from the regenerative braking is produced. This passes through a current sensor and is sent as input to the battery subsystem. In this case, the battery provides the necessary power to run the DC motor at a torque that is proportionate to the driver controller. All the references are connected to the ground.

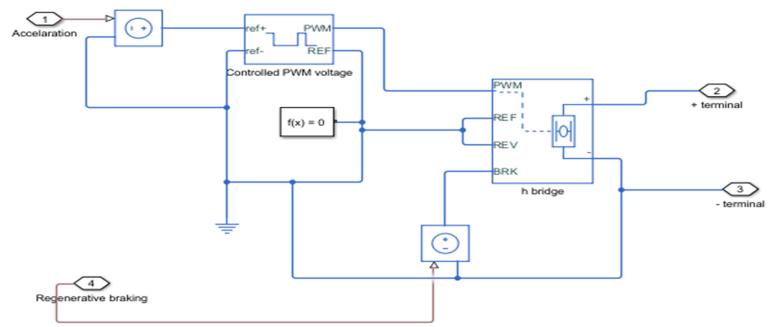
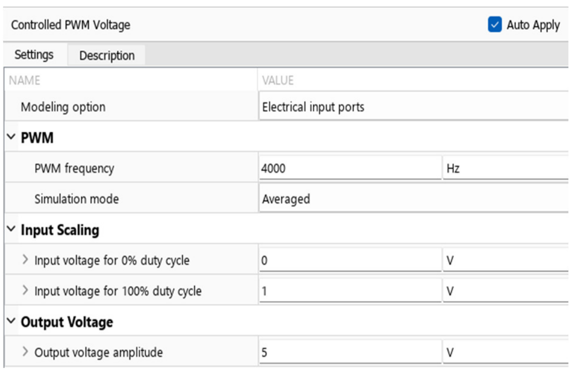


Fig. 5.1 Design of motor controller

5.1 Controlled PWM Voltage Parameter Setting:



Controlled PWM Voltage — Auto Apply

Settings | Description

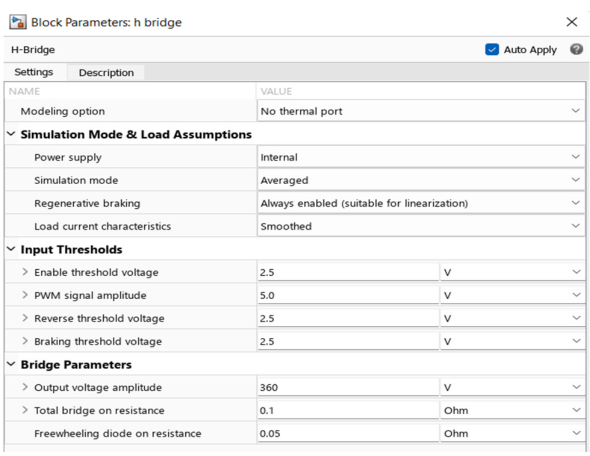
NAME	VALUE	
Modeling option	Electrical input ports	
PWM		
PWM frequency	4000	Hz
Simulation mode	Averaged	
Input Scaling		
Input voltage for 0% duty cycle	0	V
Input voltage for 100% duty cycle	1	V
Output Voltage		
Output voltage amplitude	5	V

Fig. 5.2 Parameter setting for Controlled PWM Voltage block.

These parameters are same for both Tesla Model 3 RWD and Tesla Model Y EV models. Simulation mode is selected as "Averaged" in a Controlled PWM Voltage block in MATLAB. It indicates that the block will mimic the PWM voltage control's behaviour using an averaged model. At a frequency of 4000 Hz, the block will produce a PWM signal, in which the duty cycle controls the average output voltage. The output voltage will be 5V when the duty cycle is 100% and 0V when it is 0%.

5.2 H- Bridge Parameter Setting:

These parameters are same for both Tesla Model 3 RWD and Tesla Model Y EV models.



Block Parameters: h bridge

H-Bridge — Auto Apply

Settings | Description

NAME	VALUE	
Modeling option	No thermal port	
Simulation Mode & Load Assumptions		
Power supply	Internal	
Simulation mode	Averaged	
Regenerative braking	Always enabled (suitable for linearization)	
Load current characteristics	Smoothed	
Input Thresholds		
Enable threshold voltage	2.5	V
PWM signal amplitude	5.0	V
Reverse threshold voltage	2.5	V
Braking threshold voltage	2.5	V
Bridge Parameters		
Output voltage amplitude	360	V
Total bridge on resistance	0.1	Ohm
Freewheeling diode on resistance	0.05	Ohm

Fig. 5.3 H- Bridge parameter setting.

The above figure shows Regenerative braking is always enabled, enabled threshold voltage (It is the voltage level at which the H-bridge is able to conduct forward current) is 2.5V, PWM signal amplitude is 5V, Reverse threshold voltage (It is the voltage at which the H-bridge conducts reverse current) is 2.5V, Braking threshold voltage is 2.5V, Output voltage amplitude (It is the maximum output voltage that can be produced by the H-bridge) is 360V, Total bridge on resistance is 0.1ohm, Freewheeling diode on resistance is 0.05 ohm. Under all circumstances, the H-bridge is designed to allow regenerative braking. During braking, the motor can produce power that can be sent back to the source.[6]

The H-Bridge block output is on and it is equal to the output voltage amplitude parameter value if the input signal value is higher than the value of the Enable threshold voltage parameter. The motor is powered by the H-Bridge block. The H-Bridge block's input ports are all attached to ground except PWM port. Consequently, The H-Bridge block connects the motor terminals to the power source when the motor is functioning.

6. Battery setup design

In this design, Lithium-Ion battery is considered. H bridge converter is connected to the battery through the current sensor and controlled current source blocks. The measurement port of the battery is connected to the Bus Selector to observe the variation in voltage and current through the Scope and Display.

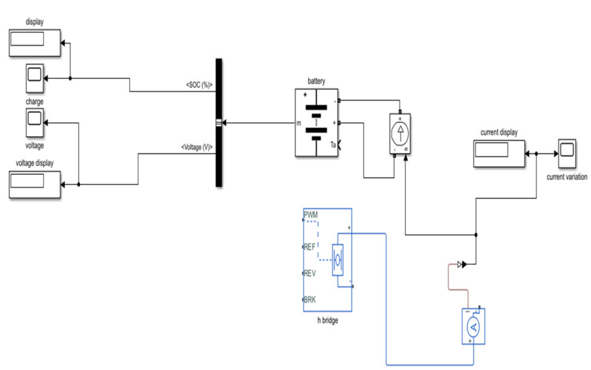


Fig. 6.1 Battery setup design.

6.1 Lithium-ion battery:

Lithium-ion batteries are the most often used rechargeable batteries in electric cars when compared to other batteries in the market. These lithium-ion batteries have a high number of cycles, high power density, high energy density (It can hold more charge in smaller space), and high operating voltage.

These batteries are very much popular and are used in laptops, cell phones etc. They power the lives of million people every day.

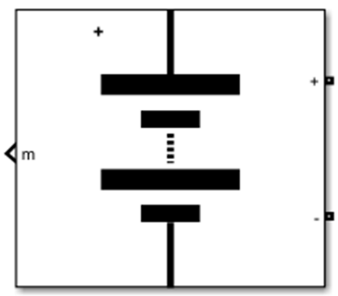


Fig. 6.2 Battery (Simulink)

Battery specifications for Tesla Model 3 RWD and Tesla Model Y RWD are different. The Nominal voltage is 360V, Rated capacity is 139Ah, Initial State of Charge of battery is 100% and Battery response time is 30 seconds are the specifications for EV battery used in Tesla Model 3 RWD.

The Nominal voltage is 350, Rated capacity is 171Ah, Initial State of Charge of battery is 100% and Battery response time is 30 seconds are the specifications for EV battery used in Tesla Model 3 RWD.

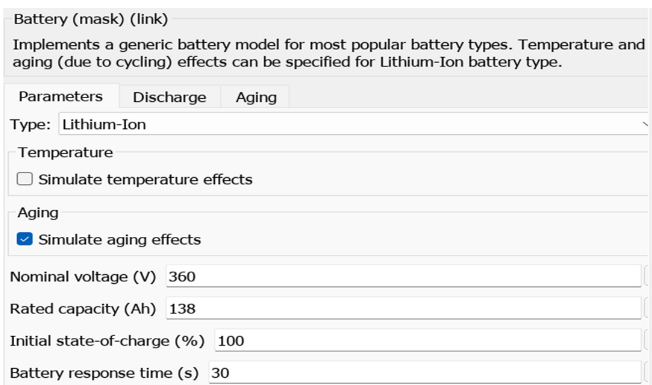


Fig. 6.3 Battery parameter setting for Tesla Model 3 EV

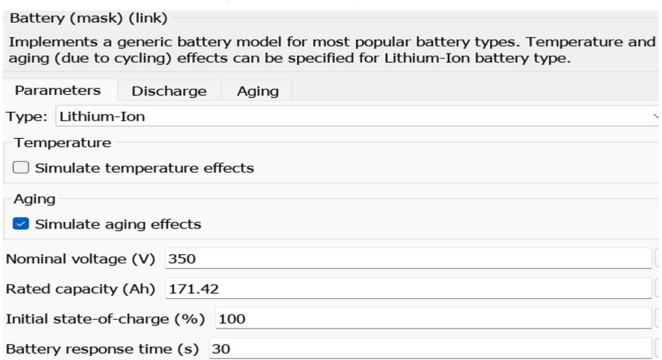


Fig. 6.4 Battery parameter setting for Tesla Model Y RWD

7. Design of PMDC motor

In Tesla Model 3 RWD and Tesla model Y RWD, Permanent Magnet Synchronous Motor is used. But in this design, PMDC motor is used because of its benefits such as lower fuel consumption, pollution, and a higher power to volume ratio. The PMDC motor's positive and negative terminals are connected to the positive and negative terminals of the H-bridge. The gear box and the motor's shaft are linked.

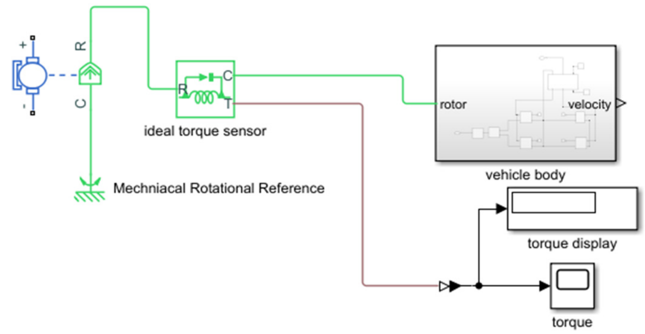


Fig. 7.1 Motor design.

7.1 PMDC Motor parameter setting:

For the two tesla models i.e., tesla model 3 and tesla model Y, PMDC motor is used for propulsion. The parameters are used are different. Parameters used in DC motor blocks for both EV models are shown in the following figures.

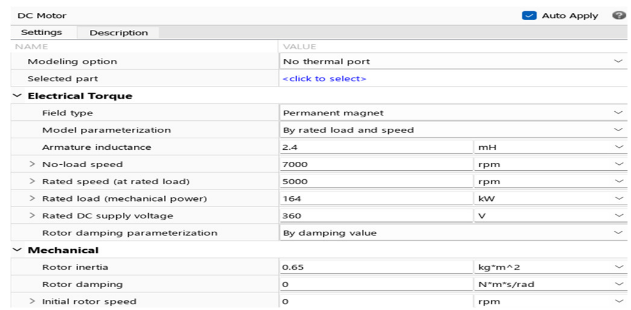


Fig. 7.2 Parameter setting for DC motor used in Tesla Model 3 (2019) EV model.

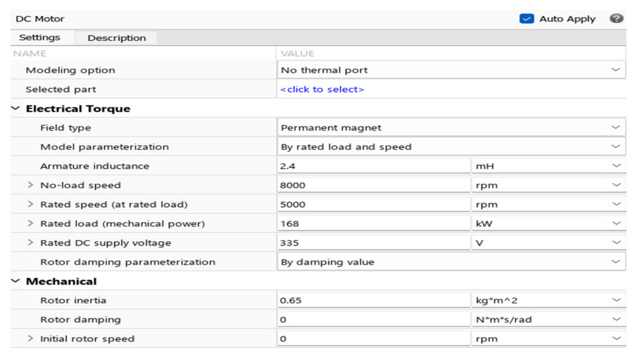


Fig. 7.3 Parameter setting for DC motor used in Tesla Model Y (2023) EV model.

8. Design of vehicle body

In this design, Simulink components like vehicle body, tire magic formula, Simple gear, PS constant, PS terminator are used. The design of vehicle body is shown in the figure 11.1. Brief description of those components is explained below.

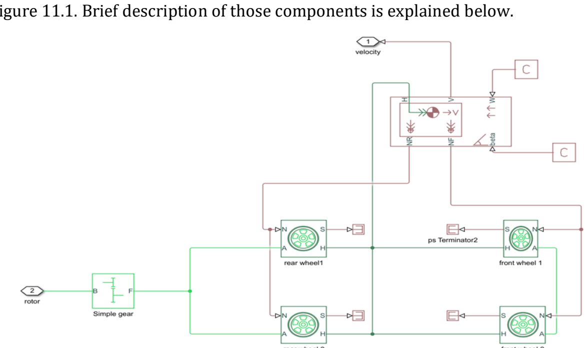


Fig. 8.1 Vehicle body design.

8.1 Simple Gear:

It represents a fixed-ratio gear or gearbox. The simple gear block has one input port and one output port.

1. B - Base (Rotational port associated with the base, or input, shaft). It is connected to motor shaft.
2. F - Follower (Rotational associated with the follower, or output, shaft). It is connected to Rear wheel axle ports.

A wheel with teeth on the rim is called a gear. If the two gears are fit together, one gear can rotate the other without flipping. This is called gear train. Each gear train has two parts.

- Driver gear – It is a gear that you turn.
- Follower gear – It is a gear that gets turned.

Gears are generally used for the following purposes.

- Direction of rotation can be reversed.
- Speed of rotation can be increased or decreased.
- Rotational motion can be moved to different axis.

If the gear train turned clockwise, then follower gear turns anti-clockwise and Vise versa. Gears are used to increase the speed. Change in gear increases the size of the driver gear. Larger the size of the driver gear, faster the speed (greater the force needed to turn it).

$$\text{Gear ratio} = \frac{\text{No.of teeth of follower gear}}{\text{No.of teeth of driver gear}} \quad (1)$$

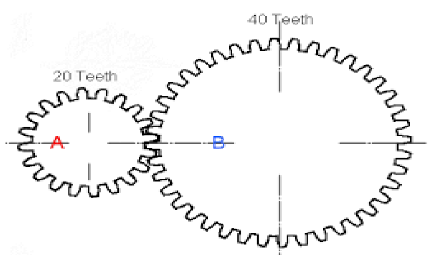


Fig. 8.2 Driver & Follower gear

A lower gear ratio causes an increase in speed. A high gear ratio causes a decrease in speed. For example, If the gear ratio is 2:1. It indicates that the output shaft of the motor rotates 2 times for every one revolution of the wheel.

When size of the follower gear is higher than the driver gear, Gear ratio is high and speed decreases. When size of the driver gear is higher than the follower gear, Gear ratio is low and speed increases.

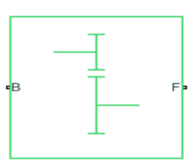


Fig. 8.3 Simple gear.

The Gear ratio is same for both the EV models i.e., Tesla Model 3 RWD (2019) & Tesla Model Y RWD (2023). The gear ratio is 9:1. It is implemented in simple gear block. Losses are not considered.

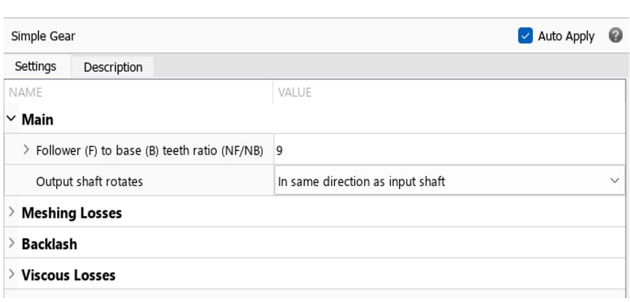


Fig. 8.4 Parameter setting for simple gear.

8.2 Tire (Magic Formula):

Tire (Magic formula) represents the longitudinal behaviour of a roadway. Tire-Road Interaction (Magic Formula) and Simscape Foundation Library Wheel and Axle blocks are used to construct the block. Tire stiffness, damping, and inertia effects are optionally included.

The tire block has the following ports:

- N - This is a normal force connecting port to the vehicle body.
- A - This is the axle signal connecting port.
- S - this is a slip signal connecting port.
- H - this is a mechanical translational port. This wheel hub transmits the thrust generated by the tire.

Two tires are connected to rear axle and other 2 are connected to front axle. The Axle terminals of the rear wheels are connected to simple gear because it is a rear wheel drive. The NR port of the car body is connected to the N port of the left side tire (Rear Axle). The NF terminal is connected to the front wheel N port of the tire on the right side. The H port on the vehicle body is connected to H terminals. S port is open.

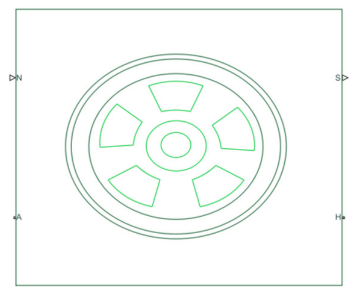


Fig. 8.5 Tire (Magic Formula)

8.3 Tire Parameter Setting:

Tire parameters used for EV models (Tesla model 3 RWD & Tesla model Y RWD) are different.

- The tire size of the vehicle (Tesla model 3 RWD) is 235/45 R18.
- The tire size of the vehicle (Tesla model Y RWD) is 255/45 R19.

The Coefficient of rolling resistance is same for both EV model's tires i.e., 0.01. The Rolling radius for Tesla model 3 RWD is 0.33435m and it is 0.35605m for Tesla model Y RWD. The rolling radius is calculated from the tire size of the vehicle. Calculation of tire radius for both vehicles is explained in the next chapter.

8.4 Calculation of Tire Radius for Tesla model 3 RWD (r):

The given tire size of the vehicle is 235/45 R18.

- 235 indicates Tire Width in mm.
- 45 indicates Aspect Ratio in %.
- 18 indicates Rim diameter in inches.

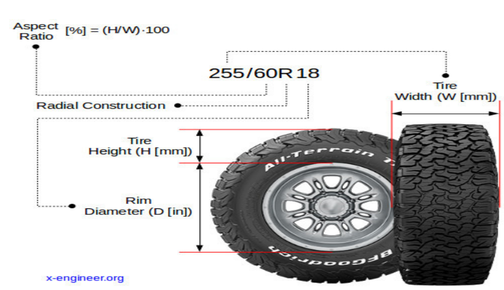


Fig. 8.6 Tire Parameters

Aspect ratio shows the relation between tire width & side wall tire height excluding rim diameter. Aspect ratio is defined as the percentage of ratio between tire side wall height and tire width. [7]

$$\text{Aspect Ratio}(AR) = \left[\frac{H(mm)}{W(mm)}\right] * 100 \qquad (2)$$

Tire Width (W) = 235mm

Aspect Ratio (AR) = 45%.

Rim diameter (D) = 18 inches [1inch = 25.4mm]

= 18*25.4

= 457.2mm

To calculate wheel diameter, we need to know:

- Rim diameter (D)
- Tire height excluding rim diameter (H).

From Eq. (2)

Tire Side wall height H = [AR*W]/100

= (45*235)/100

H = 105.75 mm

Wheel diameter = Rim diameter + 2*(height of the tire)

= 668.7mm

Wheel radius (r) = (668.7)/2 = 334.35mm

∴ Tire radius for the given vehicle is 0.33435m

8.5 Calculation of Tire Radius for Tesla model Y RWD (r):

The given tire size of the vehicle is 255/45 R19.

- 255 indicates Tire Width in mm = 255mm.
- 45 indicates Aspect Ratio in % = 45%.
- 19 indicates Rim diameter in inches = 19 inches = 482.6 mm.

To calculate wheel diameter, we need to know:

- Rim diameter (D)
- Tire height excluding rim diameter (H).

From Eq.11.2

Tire Side wall height H = [AR*W]/100

= (45*255)/100

H = 114.75 mm

Wheel diameter = Rim diameter + 2*(height of the tire)

= 712.1mm

Wheel radius (r) = (712.1)/2 = 356.05mm

∴ Tire radius for the given vehicle is 0.35605m

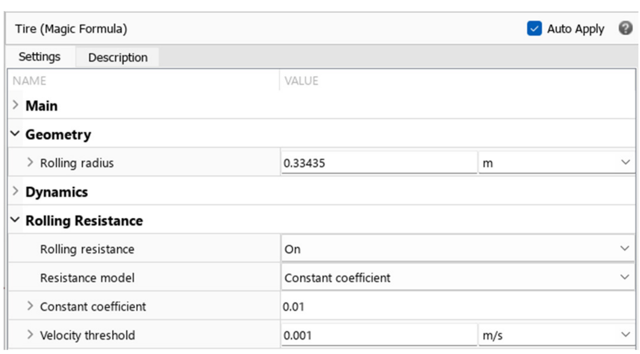


Fig. 8.7 Tire Parameter setting for Tesla model 3 RWD (2019).

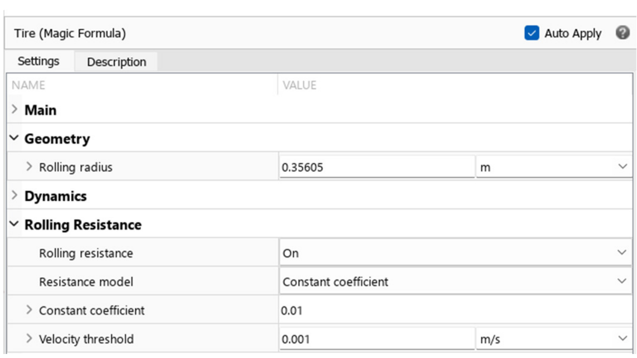


Fig. 8.8 Tire Parameter setting for Tesla model Y RWD (2023)

8.6 Vehicle Body:

The Vehicle Body block simulates a two-axle vehicle body in longitudinal motion. It can have a Centre of gravity (CG) at or below the plane of travel, and it can have the same number of wheels on each axle (e.g., two wheels on the front axle and one on the rear axle) and identical wheel sizes.

Body mass, aerodynamic drag, road inclination, and weight distribution between axles as a result of acceleration and road profile are all taken into consideration by the block. [12]

The vehicle body is having the following ports:

- NR- It is a rear axle force port.
- NF- It is a front axle force port.
- Beta - This is a road incline angle port.
- H - This port is connected to the horizontal motion of the vehicle's body.
- V - it is a vehicle longitudinal velocity port.
- W - is the Headwind speed port.

The output signals are also physical signals, just like the car body is a physical block. The left rear wheels are connected to the NR port, and the right front wheels are attached to the NF port. The PS Constant block is attached to the beta and W ports.

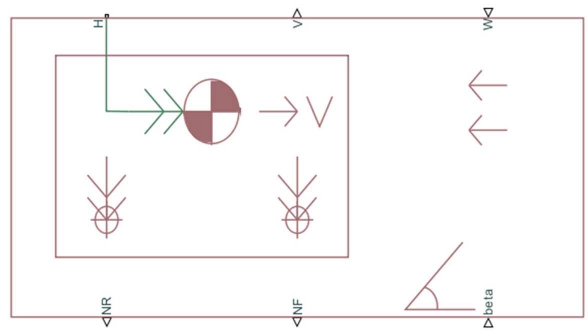


Fig. 8.9 Vehicle Body Simulink block.

8.7 Vehicle body parameter setting:

Parameters used in vehicle body block are different for Tesla Model 3 RWD and Tesla Model Y RWD. Mainly mass of the vehicle, frontal area and drag coefficient are different. They are shown in the following figures. [13]

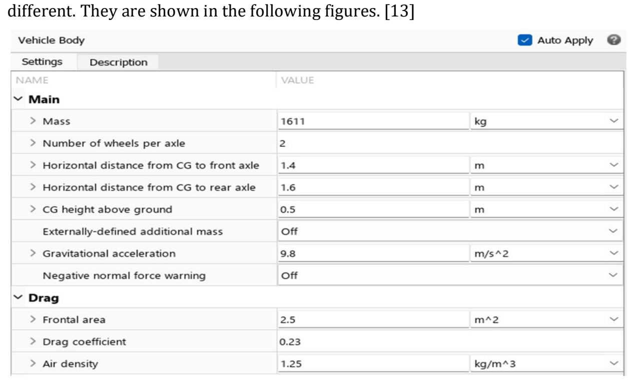


Fig. 8.10 Vehicle body parameter setting for Tesla model 3 RWD (2019).

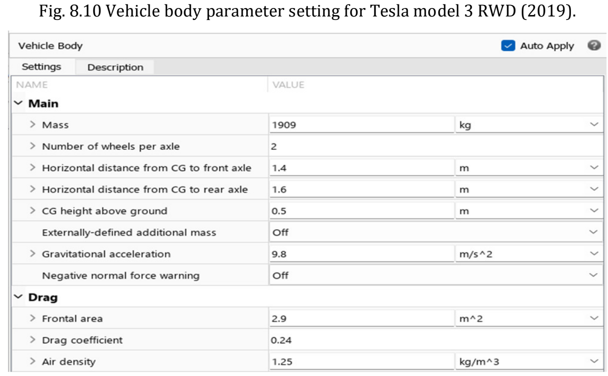


Fig. 8.11 Vehicle body Parameter setting for Tesla Model Y RWD (2023)

9. Complete EV design

Based on the driving cycle run time, a simulation time of 1028 seconds was taken. At the beginning of the simulation, the longitudinal driver block which has a controller receives the reference speed as an input from the Drive Cycle Source. The longitudinal driver block uses a PI controller which generates normalized signals for braking and acceleration based on reference and feedback velocities.[14] The motor controller block receives orders for acceleration and deceleration.

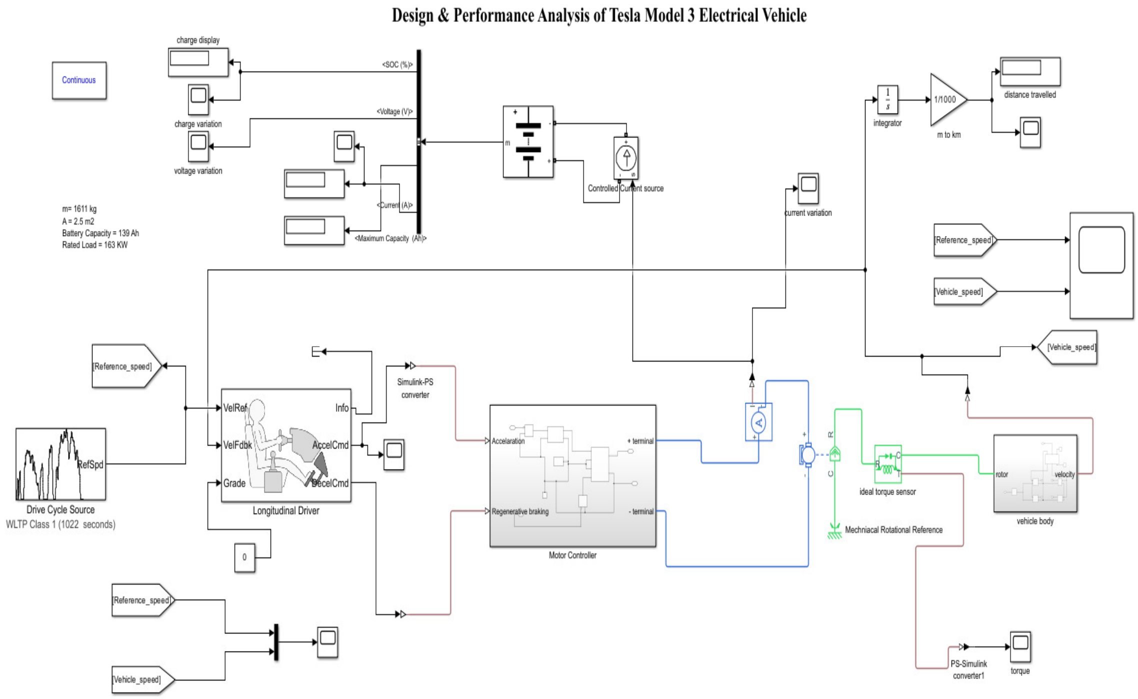


Fig. 9.1 Complete EV design

10. Results and its analysis

Both the 2019 Tesla Model 3 and the 2023 Tesla Model Y have pros and cons of their own. When the two simulations are compared, an empirical difference in the findings will show up because of the variations in the vehicle body, battery, and motor metrics. The outcomes of the co-dependent simulations of battery capacity, acceleration, and velocities will be influenced by many specific vehicle characteristics.

10.1 Reference Vs Actual Velocity Results:

The pre-defined input to the vehicle id WLTP Class 1 drive cycle. Its simulation run time is 1022 seconds. Set the simulation run time as 1022 seconds. After successful completion of simulation, following results are obtained.

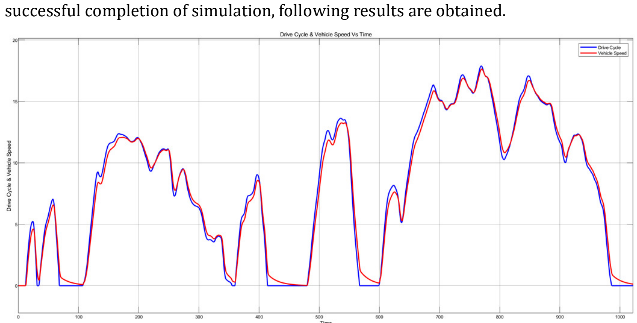


Fig. 10.1 Reference Vs Actual Velocity for Tesla Model 3 RWD (2019).

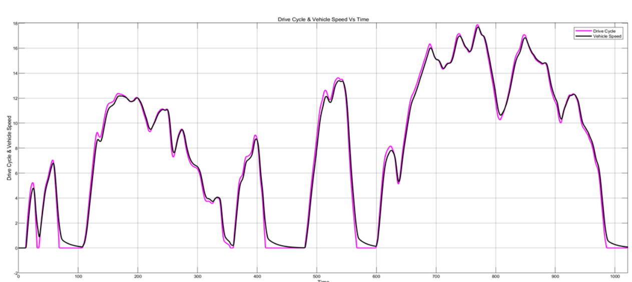


Fig. 10.2 Reference Vs Actual Velocity for Tesla Model Y RWD (2023).

The WLTP Class 1 drive cycle is shown in pink in the above picture, while the vehicle speed is shown in black.

The Tesla Model 3 RWD and the Tesla Model Y RWD can be visually compared by examining Figures 14.1 and 14.2 of the Reference versus Actual Velocity Scope data. The Tesla Model 3's rated motor load of 163 KW beats the Tesla Model Y's 168 KW motor in most speed-related aspects when the different simulation parameters, shown in Table 5.1. The benefit of Powerful motor of Model 3 is that it accurately follows the reference speed compared to Tesla Model Y. The Model 3 has the benefit with a little smaller frontal area (2.5 m^2) and drag coefficient (0.23) whereas the frontal area and drag coefficient of Model Y is 2.9 m^2 and 0.24). The smaller change in the speed comparisons is caused by the car's overall drag.

10.2 Range and SOC Results:

The vehicle (Tesla Model 3RWD) travelled 8 Km with the given drive cycle. The state of charge of the battery is reduced from 100% to 97.05%. The spikes in the graph indicates Regenerative braking. The Range of Tesla Model Y RWD is 8.119 Km and state of charge is 96.5%. There is 100m difference in range between the two EV models.

The below figures show the Range and State of charge of Tesla Model 3 RWD (2019) and Tesla Model Y RWD (2023).

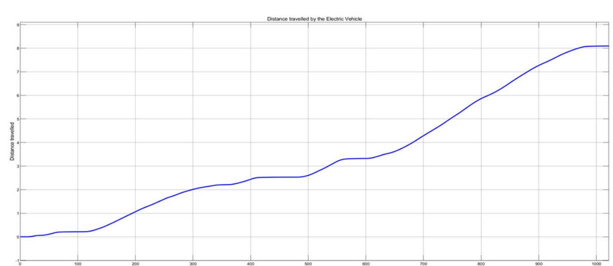


Fig. 10.3 Range of Tesla Model 3 RWD (2019)

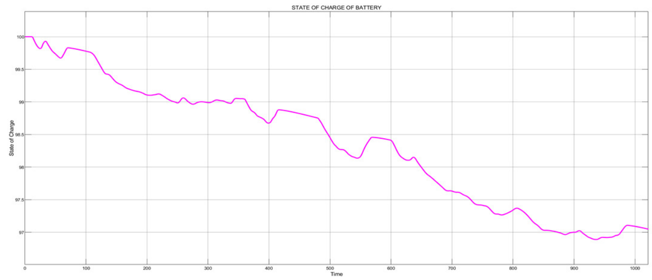


Fig. 10.4 SOC of Tesla Model 3 RWD (2019)

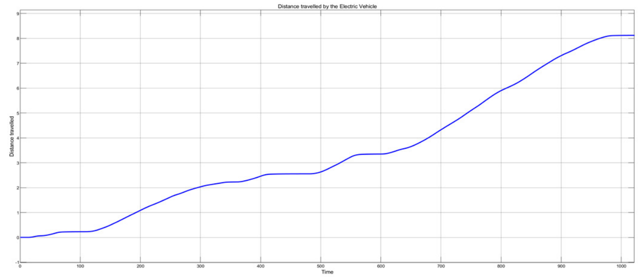


Fig. 10.5 Range of Tesla Model Y RWD (2023)

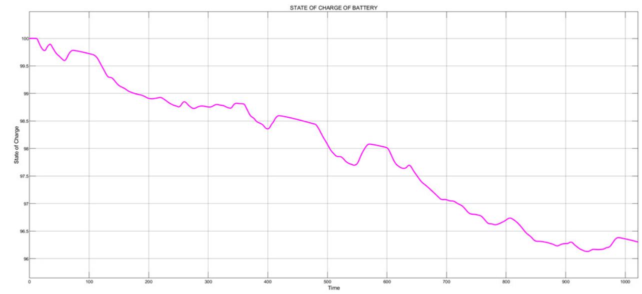


Fig. 10.6 SOC of Tesla Model Y RWD (2023)

Each car's battery starts out fully charged at drive cycle time 0 seconds and gradually discharges by powering the motor and H Bridge while it tries to match the drive cycle's reference speed. During the drive cycle, regenerative braking restores a portion of the battery's lost energy. The regenerative braking has larger impact on both EV models because the motor is acting as generator and battery capacity has been increased. The spikes in fig. 14.4 and 14.6 clearly indicates regenerative braking.

The Simulation run time is 1022 seconds. After running the Tesla Model 3 EV for 1022 seconds, its range is 8km and SOC is 97%. Because of large battery rating (139 Ah), it can sustain the charge. Similarly, after running Tesla model Y for 1022 seconds, its range is 8.1 Km and SOC is 96.5%. Its battery capacity is 171 Ah i.e., 32 Ah greater than Tesla Model 3 battery. Even though the battery capacity is higher (171 Ah), SOC is 96.5% (less than Tesla model 3 EV i.e., 97%). This is because of high mass, drag coefficient and frontal area of Tesla Model Y EV compared to Tesla Model 3 EV.

Table 3
Range and SOC of Tesla Model 3 RWD (2019) for different drive cycles:

S. No	**Drive Cycle**	**Simulation time**		**Range (km)**	**Initial SOC (%)**	**SOC (%)**
		Seconds	**Minutes**			
1.	WLTP class 1	1022	17	8.092	100	97.05
2.	ECE R15 (single cycle)	195	3.25	1.003	100	99.48
3.	WLTP Class 3	1800	30	22.06	100	93.44
4.	City Suburban heavy cycle.	1700	28.3	10.76	100	95.4
5.	Artemis urban	993	16.5	4.906	100	97.4

Table 4
Range and SOC of Tesla Model Y RWD (2023) for different drive cycles:

S. No	**Drive Cycle**	**Simulation time**		**Range (km)**	**Initial SOC (%)**	**SOC (%)**
		Seconds	**Minutes**			
1.	WLTP class 1	1022	17	8.119	100	96.5
2.	ECE R15 (single cycle)	195	3.25	1.028	100	99.35
3.	WLTP Class 3	1800	30	23.18	100	91.33
4.	City Suburban heavy cycle.	1700	28.3	10.82	100	94.23
5.	Artemis urban	993	16.5	5.126	100	97.4

11. Conclusions

Simulink in MATLAB created an efficient comparative analysis by encoding the specifications of various battery-powered vehicles into code. Electric vehicle operating in the real world can be demonstrated and evaluated by using MATLAB/Simulink. Vehicle performance was mostly determined by significant factors such motor design, system voltage, and the physical structure of the vehicle. By using the MATLAB/Simulink as the design tool, the performance of electric vehicle has been observed.

The Tesla Model 3's rated motor load of 163 KW beats the Tesla Model Y's 168 KW motor. Model 3 accurately follows the reference speed compared to Tesla Model Y. This is because the Model 3 has the benefit with a little smaller frontal area (2.5 m^2) and drag coefficient (0.23) whereas the frontal area and drag coefficient of Model Y is 2.9 m^2 and 0.24.

Range and SOC of Tesla Model RWD is 8km and 97%. Similarly, the range and SoC of Tesla Model Y RWD is 8.1 Km and 96.5%. Even though the battery capacity of Tesla model Y is higher (171 Ah) than Tesla Model 3 (139Ah), SOC is 96.5% (less than Tesla model 3 EV i.e., 97%). This is because of high mass, drag coefficient and frontal area.

This method can be used by the manufacturers or Customers to analyze the performance of EV with a pre-defined velocity profile and to predict the vehicle operation in real world environment. Customers can evaluate electric vehicles for their requirements in a simple and effective way with the help of the comparative approach of analysis. MATLAB software allows extensive simulation customization for most scenarios that are significant to users. To differentiate themselves from competitors, manufacturers need to offer distinctive, lightweight, powerful, and efficient designs.

Declaration of Competing Interest

No journals have received the manuscript as of yet, and it has not been published before. Therefore, no personal or professional conflicts of interest with this manuscript. This study does not have any funding support.

References

[1] Hannah Ritchie and Pablo Rosado, "Fossil Fuels," [Online]. Available: https://ourworldindata.org/fossil-fuels.

[2] "2019 Tesla Model 3 Standard Range RWD - Specifications," [Online]. Available: https://www.evspecifications.com/en/model/bc5896.

[3] "Build Full Electric Vehicle Model," [Online]. Available: https://in.mathworks.com/help/autoblks/ug/explore-the-electric-vehicle-reference- application.html.

[4] Dileep Kumar Kohar, Akshaya K. Pati and Sarita Nanda, "Design Approaches and Performance Analysis of Electric Vehicle using MATLAB/Simulink," *2023 IEEE International Students' Conference on Electrical, Electronics and Computer Science(SCEECS)*, pp. 1-6, 2023.

[5] Slough J, Belcher M, Tsui T and Bhattacharya S, "Modeling and Simulation of Electric Vehicles Using Simulink and Simscape," *In 2021 IEEE 94th Vehicular Technology Conference (VTC2021-Fall)*, pp. 01-06, 2021.

[6] "How to calculate wheel radius," [Online]. Available: https://x-engineer.org/calculate-wheel-radius/.

[7] Inoue Y, Kosaka T, Matsumori H and Matsui N, "Modeling and Simulation of Battery-powered Electric Vehicle on MATLAB/Simulink," *In2021 24th International Conference on Electrical Machines and Systems (ICEMS)*, pp. 694-698, 31 Oct 2021.

[8] Hashemnia N and Asaei B, "Comparative study of using different electric motors in the electric vehicles," *In2008 18th international conference on electrical machines,* pp. 1-5,6 Sep 2008.

[9] Vempalli SK, Ramprabhakar J, Shankar S and Prabhakar G, "Electric vehicle designing,modelling and simulation," *In2018 4th International Conference for Convergence in Technology (I2CT)*, pp. 1-6, 27 Oct 2018.

[10] Abulifa AA, Ahmad RR, Soh AC, Radzi MA and Hassan MK, "Modelling and simulation of battery electric vehicle by using MATLAB-Simulink," *In2017 IEEE 15thStudent Conference on Research and Development (SCOReD,* pp. 383-387, 13 Dec 2017.

[11] Pacejka H, "Tire and vehicle dynamics," *Elsevier,* 8 Dec 2005.

[12] Dr.T.S.N.G. Sarada Devi and Mrs. G. Jhansi Rani, SPECIAL HYBRID ELECTRICVEHICLES, vol. 1, LAMBERT, 2023.

[13] B. Anil Kumar and G. Jhansi Rani, "Design and Performance Analysis of Battery Electric Vehicle using MATLAB/Simulink," *Journal of Technology,* vol. 14, no. 3, p. 13, 2024.

[14] Poornesh K, Nivya KP, Sireesha K. A comparative study on electric vehicle and internal combustion engine vehicles. In2020 International Conference on Smart Electronics and Communication (ICOSEC) 2020 Sep 10 (pp. 1179-1183). IEEE.

[15] Chalawadi V, Amminabhavi SP, Jadhav AS, Pawar R, Kanamadi MS, Patil RS. Design and Analysis of PMDC Motor for Electric Vehicles. In2023 Advanced Computing and Communication Technologies for High Performance Applications (ACCTHPA) 2023 Jan 20 (pp. 1-5). IEEE.

[16] Yashwanth SD, Sathvik HR, Nikshep HG. Electric Vehicle with Regenerative Braking Model using MATLAB-Simulink. In2023 IEEE Renewable Energy and Sustainable E-Mobility Conference (RESEM) 2023 May 17 (pp. 1-6). IEEE.

[17] Billah SB, Islam KK. Regenerative braking characteristics of PMDC motor by applying different armature voltage. In2016 2nd International Conference on Electrical, Computer & Telecommunication Engineering (ICECTE) 2016 Dec 8 (pp. 1-4). IEEE.

[18] Billah SB, Islam KK. Regenerative braking characteristics of PMDC motor by applying different armature voltage. In2016 2nd International Conference on Electrical, Computer & Telecommunication Engineering (ICECTE) 2016 Dec 8 (pp. 1-4). IEEE.

[19] G. Jhansi Rani, P. Srinivas, "Implementation of Dual Active Full Bridge DC-DC Converter Using Phase Shift Control Technique" International Journal of Creative Research Thoughts, Volume 6; Issue: 2 April 2018, ISSN: 2320-2882, DOI: http://doi.one/10.1729/Journal.35793.

[20] G. Jhansi Rani, P. Srinivas, "Performance Exploration of Single-Phase DAB DC-DC converter under load variation", International Research Journal of Engineering and Technology, Volume: 10, Issue: 1029-1035, April-2023, ISSN: 2395-0072.

[21] G. Jhansi Rani, E. Vidyasagar, "Control of PV Integrated DAB Under Shading Conditions Using Improved Incremental Conductance MPPT Scheme" Journal of Harbin Engineering University, Volume 44, Issue 11, pages: 664-650, NOV-2023. ISSN: 1006-7043.