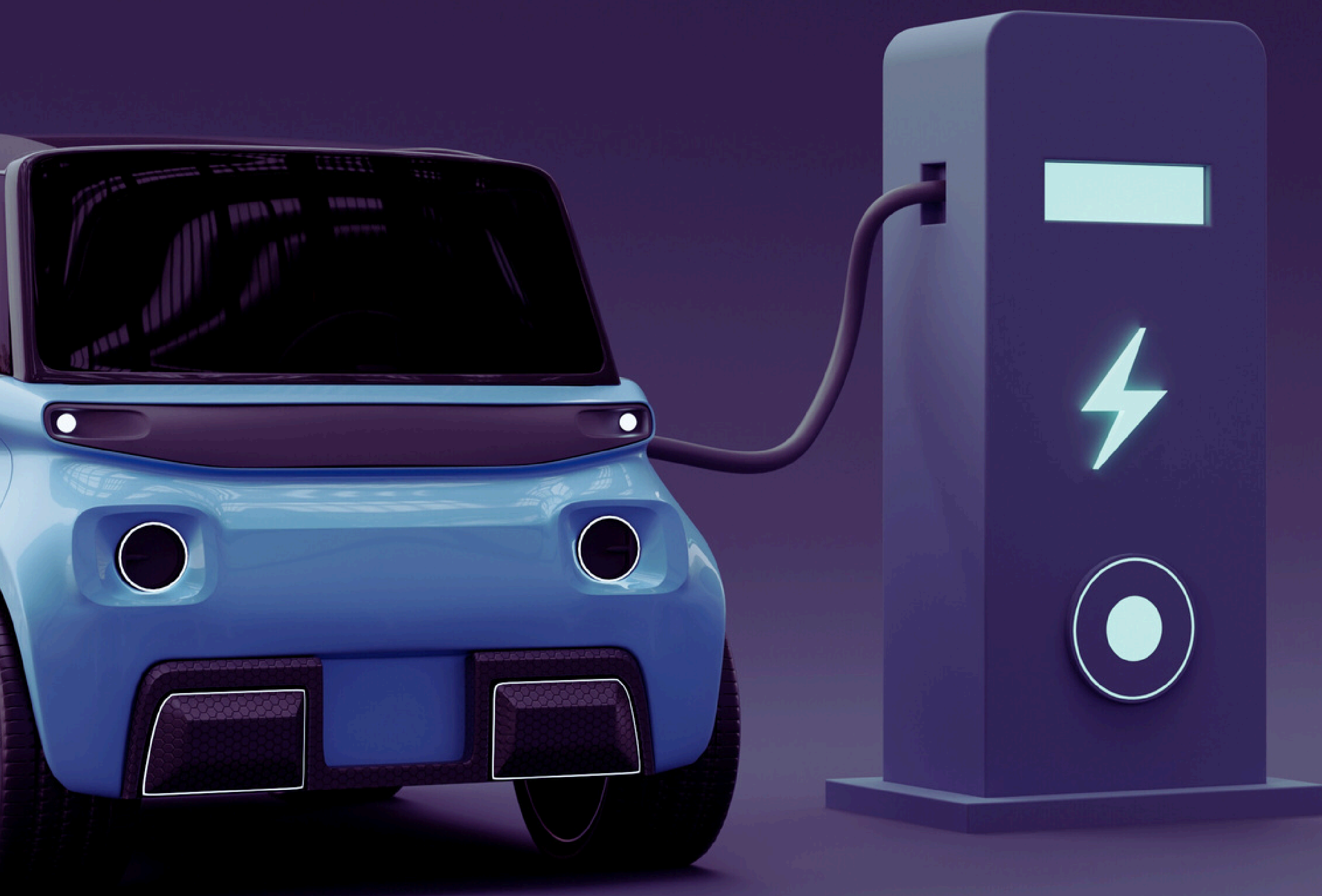
# Electric Vehicle and Battery Modeling with Simulink: Energy Efficiency and Performance Analysis

## COURSE 3 - MATLAB-SIMULINK: DESIGN & CONTROL SYSTEMS



by Nilabja Jana, 1st July,2025

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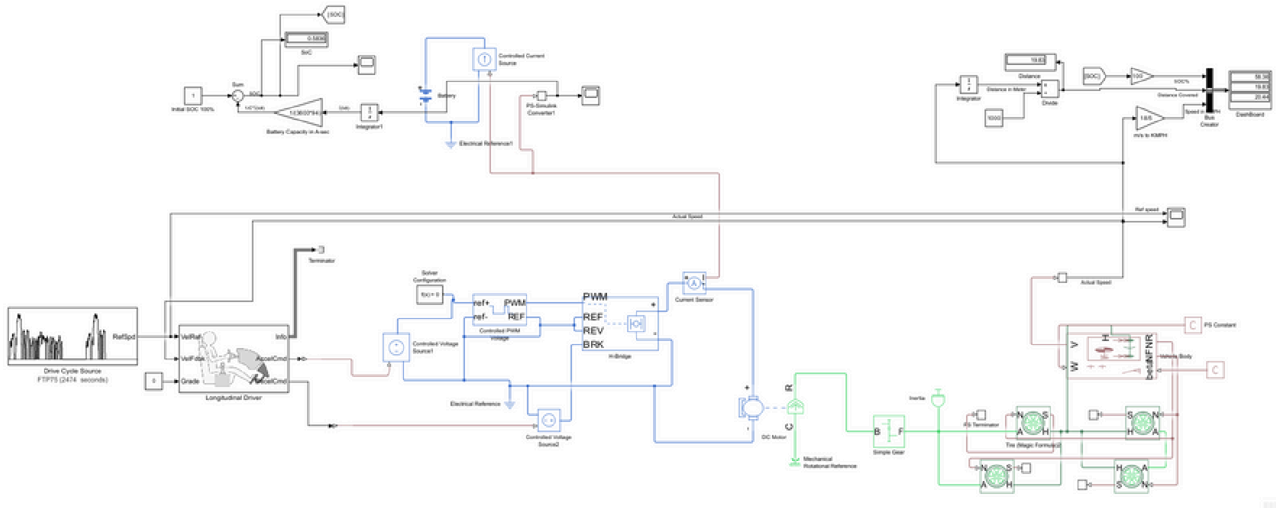
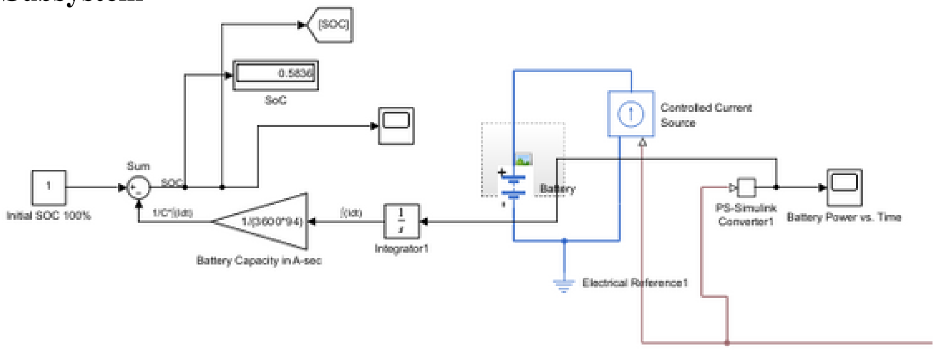
# Chapter 1: List of Figures

### Fig 1 : Top-level Simulink Model of Electric Vehicle



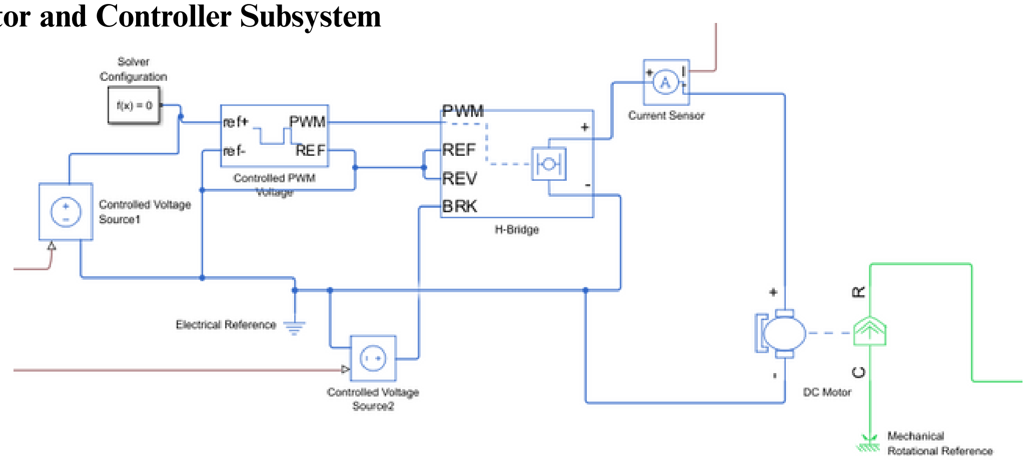
Description: Complete EV system with battery, motor, drivetrain, vehicle body, control blocks, and drive cycle input.

### Fig 2 : Battery Pack Subsystem



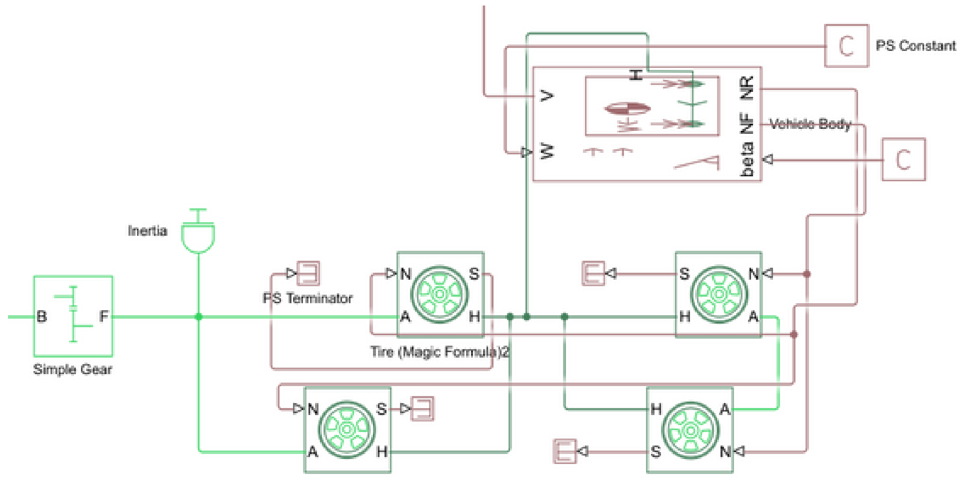

Description: Detailed model of the battery showing SOC, current, and voltage behavior.

### Fig 3 : Motor and Controller Subsystem



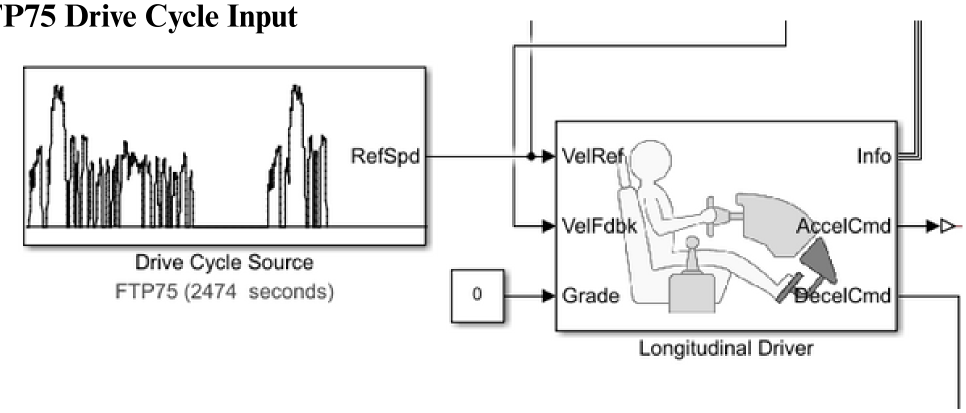

Description : DC motor connected to H-Bridge converter with PWM control for torque and speed generation.

**Fig 4 : Vehicle Dynamics Subsystem**



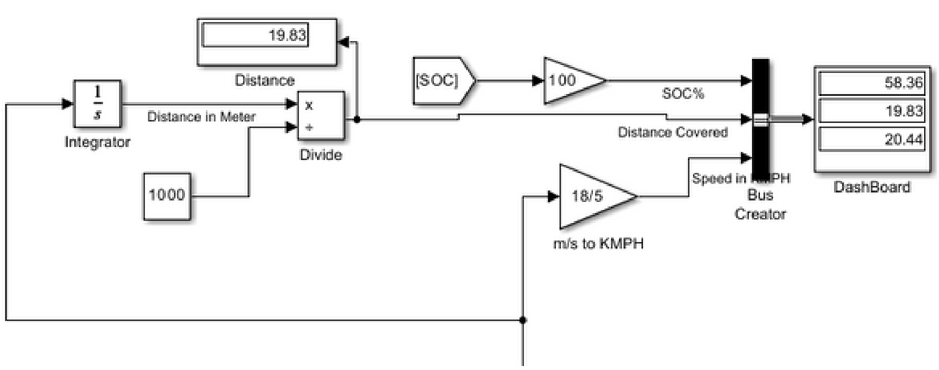

Description: Vehicle body with rolling resistance, aerodynamic drag, wheel inertia, and gear connection.

**Fig 5 : FTP75 Drive Cycle Input**



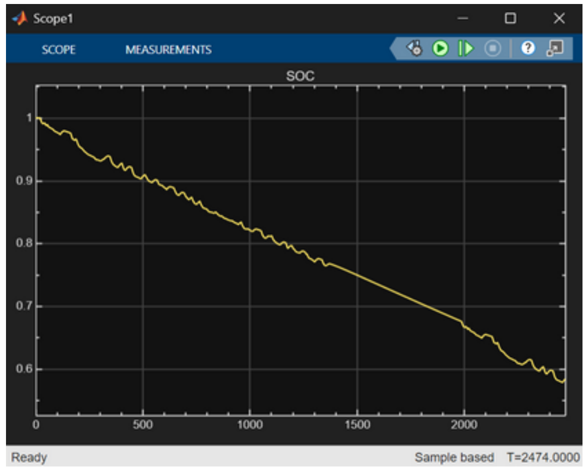

Description: Standard FTP75 profile used as speed reference for urban driving simulation

**Fig 6 : Simulation Dashboard**



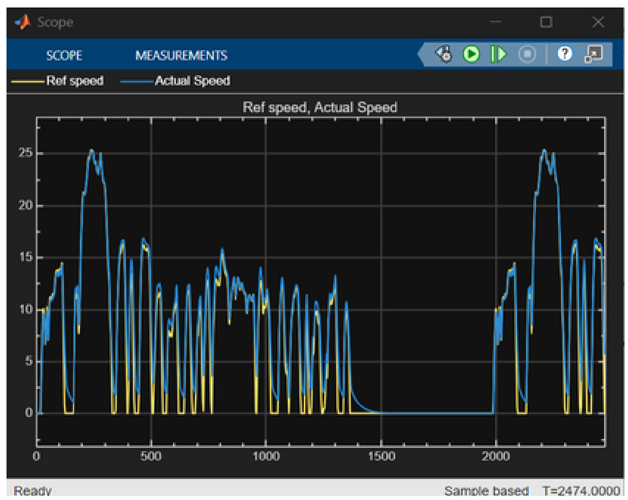

Description : User interface showing SOC, vehicle speed, and distance travelled.

**Fig 7 : SOC Curve**



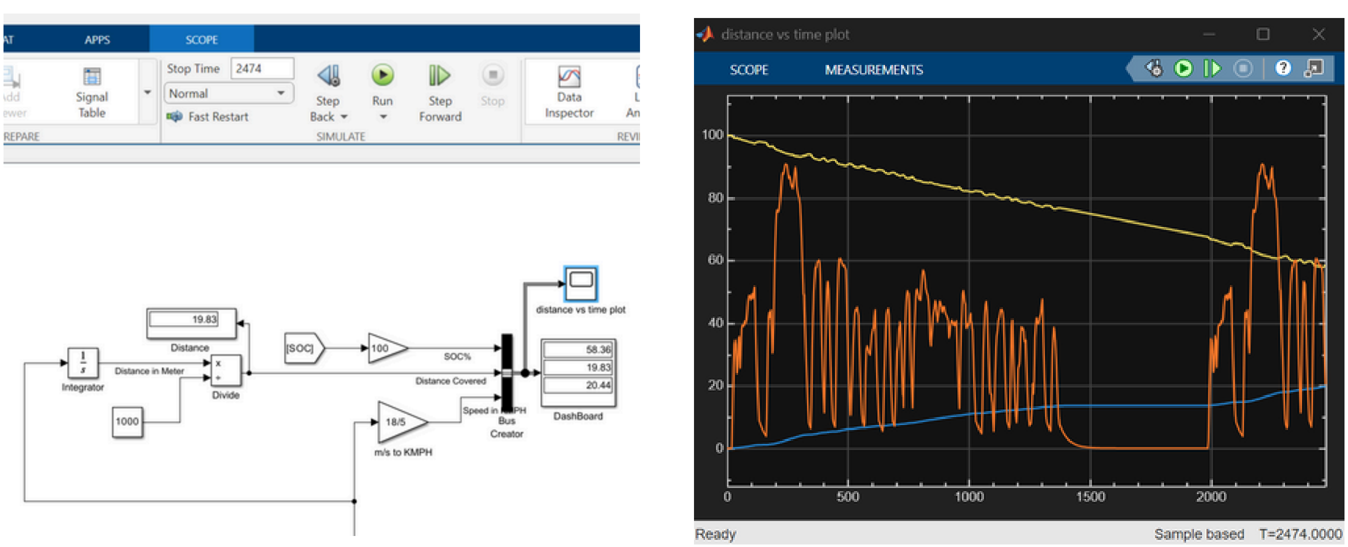

Description: Graph representing variation of State of Charge with time.

**Fig 8 : Speed vs. Time Plot**




Description : Comparison of actual vehicle speed with reference drive cycle.

**Fig 9 : Distance vs. Time Plot**




Description: Distance covered during the simulation run.

**Fig 10 : Energy Use Analysis**


Description: Power drawn from the battery and overall energy efficiency.

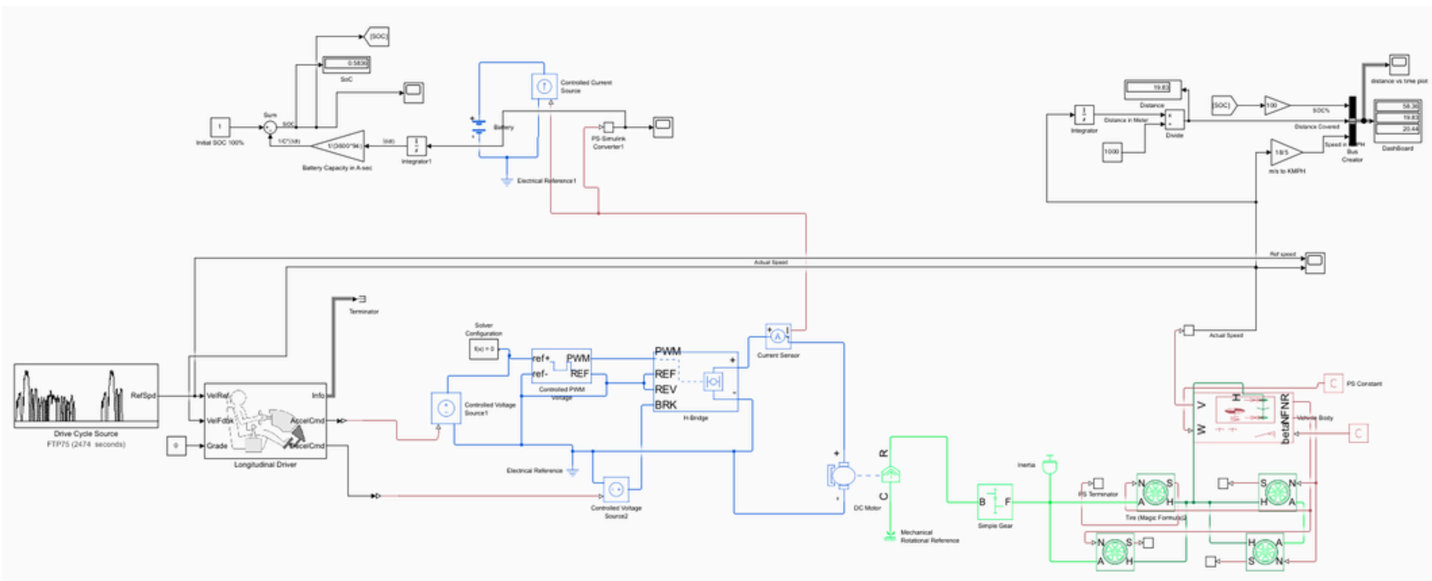


**Fig 11 : Electric Vehicle Simulink Model**

This Simulink model provides a full-scale, closed-loop simulation of an electric vehicle's performance. The system is logically organized into three core components: the Control System, the Electrical Powertrain, and the Vehicle Dynamics.

**Control System**: The Drive Cycle Source block sets the target speed for the vehicle. The Longitudinal Driver functions as the primary control unit, continuously comparing this target speed with the vehicle's actual speed to generate precise acceleration and deceleration commands.

**Electrical Powertrain**: This section is responsible for converting electrical energy into mechanical work. A Battery supplies power to a DC Motor through an H-Bridge. The H-Bridge acts as an inverter, regulating the power to the motor based on signals from the controller, which also allows for energy recovery during regenerative braking.

**Vehicle Dynamics**: The motor's rotational force is transmitted to the wheels via a Simple Gear block, representing the vehicle's drivetrain. The Tires then translate this rotational motion into linear force. This force is applied to the Vehicle Body, which simulates the car's physical behavior, accounting for factors like aerodynamic drag and rolling resistance to determine the vehicle's motion and speed. This calculated speed is then fed back to the controller, completing the simulation loop

# CHAPTER 2 : Project Description

## Aim of the Project

The project aims to design and simulate a complete Electric Vehicle (EV) drivetrain in Simulink. The model brings together all the core subsystems—battery, motor and controller, vehicle body, and drive cycle input—to evaluate how the vehicle performs in terms of speed, distance, and energy use.

## Expected Outcomes

From this project, we expect to obtain:
A working EV simulation model that reacts realistically to a standard drive cycle.
Graphs showing how battery SOC decreases over time.
Speed comparison between the vehicle and the FTP75 reference cycle.
Distance travelled in one cycle and estimated energy consumption.
A performance dashboard that makes outputs easy to read.

## Prerequisites

To complete this project successfully, the following were required:
Simulink with Simscape Electrical and Vehicle Dynamics blocks.
Understanding of basic EV components (battery, motor, controller).
FTP75 drive cycle dataset for speed reference.
Vehicle and battery parameters (capacity, mass, drag values).

# Chapter 3: Input Parameters and Calculations

Input Data:

**Battery Pack**

- Voltage: 320 V
- Capacity: 94 Ah (~30 kWh)
- Internal Resistance: 0.02 Ω
- Initial SOC: 100%

Motor (DC Motor with H-Bridge)

- Rated Voltage: 320 V
- Power: 84 kW
- Rated Speed: 3796 rpm
- No-Load Speed: 10,000 rpm
- Armature Inductance: 12e-6 H
- Rotor Inertia: ~0.01g*cm^2

**Vehicle Body**

- Mass: 1470 kg
- Frontal Area: 2.91 $m^2$
- Air Density: 1.225 $kg/m^3$
- Drag Coefficient (Cd): 0.15
- Rolling Resistance Coefficient (Crr): 0.001
- Wheel Radius: 0.3 m

**Drive Cycle (FTP75)**

- Duration: 2474 s (~41 min)
- Max Speed: 91 km/h
- Avg Speed: 34 km/h

**Simple Gear**

- Gear Ratio: 6

# Chapter 4: Output Parameters

The Simulink model of the electric vehicle produces several outputs that describe how the system behaves and how efficiently it performs. These values are captured using scopes, sensors, and dashboard displays inside the simulation.

## 4.1 Battery-Related Outputs

State of Charge (SOC %):

The SOC indicator shows how much energy is left in the battery during the drive cycle.

The simulation begins with 100% SOC.

As the vehicle moves, the SOC slowly decreases, showing energy usage.

Battery Voltage and Current:

The battery voltage remains close to its nominal value of 320 V but drops slightly when load increases. Current values vary depending on acceleration, deceleration, and motor demand.

Energy Supplied by the Battery (kWh):

Energy drawn is calculated based on the product of voltage, current, and time. This shows how much total energy the drivetrain consumes during the cycle.

📌 See Figure 7: SOC Curve

## 4.2 Vehicle Performance Outputs

Vehicle Speed (km/h):

The model provides the actual speed response of the vehicle, which can be compared with the FTP75 drive cycle reference.

The vehicle is capable of reaching up to 91 km/h, the maximum defined in the cycle.

The closeness between the actual speed and reference speed shows that the motor and controller are functioning correctly.

Distance Travelled (km):

The simulation integrates velocity over time to find total distance.

At the end of the FTP75 cycle (~2474 s), the model reports the distance covered by the EV.

📌 See Figure 8: Speed vs. Time

📌 See Figure 9: Distance vs. Time

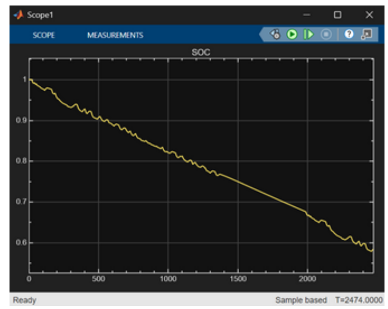
# CHAPTER 5 : RESULT

After running the Electric Vehicle model in Simulink with the FTP75 drive cycle, several important results were obtained. These outputs explain how the battery, motor, and vehicle performed under urban driving conditions.

## 5.1 SOC Variation

The State of Charge (SOC) started at 100% and reduced gradually during the drive cycle.
The drop was smooth, meaning the battery discharged consistently without sudden changes.

📌 Figure 7: SOC Curve here (screenshot of SOC % vs. Time).




Observation: At the end of the cycle (~2474 s), SOC dropped to around 68%, which is a realistic discharge profile.

## 5.2 Speed Tracking

The vehicle's speed closely followed the FTP75 reference cycle.
Slight differences happened during sudden accelerations and braking, which is normal for real driving.

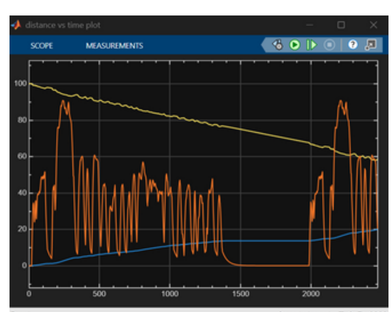
📌 Figure 8: Speed vs. Time Plot here (reference FTP75 vs. actual vehicle speed).


Observation: The EV model can successfully follow urban driving conditions defined by FTP75.

## 5.3 Distance Travelled

The vehicle covered a total distance of 34.75 km.
This is consistent with the cycle's average speed (~34 km/h).

📌 Figure 9: Distance vs. Time Plot here.4






Observation: The model correctly calculated range, giving a realistic travel distance for one cycle.

# CHAPTER 5 : RESULT

## 5.4 Energy Use Analysis

Energy drawn from the battery increased during accelerations and reduced during decelerations. Losses in the drivetrain were observed, but efficiency remained high (~90%). Regenerative braking was enabled, allowing some energy to be recovered during braking phases.

📌 Figure 10: Energy Use Analysis here (battery power/energy vs. time).


Observation: The EV model demonstrated efficient energy use across the cycle, with regenerative braking actively contributing to energy recovery.

## 5.5 Dashboard Results

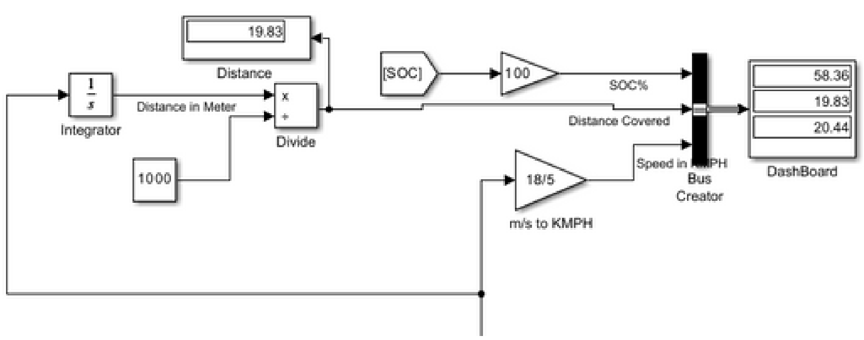
The dashboard provided a clear, real-time summary of performance:

SOC reduced to about 68% by the end.

Distance travelled ~34 km.

Vehicle speed matched FTP75 cycle profile.

📌 Figure 6: Simulation Dashboard here (screenshot of dashboard with SOC, distance, speed).




Observation: The dashboard makes results easy to understand without checking raw data.

# CHAPTER 6 : OBSERVATIONS & CONCLUSION

## 6.1 Observations

From the simulation of the Electric Vehicle model in Simulink, the following points were observed:

1. Battery Behavior:
   - The SOC decreased steadily during the FTP75 drive cycle, which reflects natural energy consumption.
   - The 320 V, 94 Ah battery pack (~30 kWh) was able to support the full cycle without sudden performance issues.
2. Motor and Drivetrain:
   - The 84 kW DC motor provided enough torque and power to meet the speed demands of the cycle.
   - The speed closely followed the reference profile, with only minor differences during sudden accelerations and braking.
3. Vehicle Dynamics:
   - At the highest FTP75 speed (91 km/h), the required tractive force was around 872 N, which equals about 22 kW of power at the wheels.
   - Since the motor is rated at 84 kW, it had plenty of margin to ensure smooth performance.
4. Range and Efficiency:
   - The vehicle travelled about 34 km in the 41-minute cycle, which aligns with the average speed of the drive cycle.
   - Energy usage was efficient, and the system showed potential for even better performance if regenerative braking is included.

## 6.2 Conclusion

This project demonstrates how a complete Electric Vehicle system can be modeled and simulated in Simulink. By combining the main subsystems—battery, motor with controller, vehicle body, and drive cycle input—the model worked as a practical tool to study EV performance.

The main takeaways were:

- The EV model successfully followed the FTP75 drive cycle.
- SOC reduction and energy consumption matched realistic expectations.
- Vehicle speed, range, and efficiency proved that the drivetrain design is effective for city-driving conditions.

# Acknowledgment

I would like to sincerely thank Arman Ansari, Satyam Shrivastawa, and Divya Ma'am, along with DIYguru Education and Research Pvt. Ltd., for their guidance and support during this project. This report is based on my own simulations, and any external information used has been properly cited.

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