# Performance Evaluation of an Electric Vehicle using MATLAB Simulink


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***Abstract*—Auto mobile industry is constantly evolving with the help of advanced technology that is being developed. These advanced technologies allow manufacturers to introduce new high performance electric vehicles with better driving range and battery capacity. Since, electric vehicles have demonstrated a significant potential to minimize the usage of petroleum products and other sources of fuel that emits significant amounts of carbon dioxide. Many consumers prefer electric vehicles which have powerful motor with high-capacity battery and better driving range. This can be very complicated for a typical buyer when buying an electric vehicle. This paper demonstrates a tool for assessing the performance of different models of electric vehicles with each other on the basis of factors like motor rating, battery capacity and driving range. The central theme of this paper revolves around two models of electric vehicles, the Tata Nexon EV, and the BMW i4 eDrive40, to assess the comparative performance. The simulation model for electric vehicles is introduced using MATLAB software's Simulink and Simscape environment considering different variables related to the vehicle motor, battery, and body. These include drive cycle source, DC motor, PWM motor controller, and electric vehicle framework in testing. Analysis of results from the simulation model shows the two different experimental vehicle model differences to help the buyer in acquiring an electric vehicle according to their requirements.**



***Index Terms*—Electric Vehicles, Performance Assessment, Vehicle Simulation, Simulink, Simscape.**


## I. Introduction

The electric vehicle (EV) simulation model presented here gives an in-depth analysis of vehicle parameters which are very important such as drive train, power of motor, battery capacity and mass of the vehicle. The simulation file has been separated into three different major sections. The first is reference velocity generator which includes Simulink block, and it is responsible for delivering a reference velocity for comparison of corresponding results. The DC motor and its controller, which determine the speed of the motor and the output power derived from pulse width modulation (PWM), are given in the next section. The final section is accountable for the gear ratio and gearbox of the vehicle, as well as the wheel configuration parameters like mass of the vehicle, drag coefficient and various characteristics of the vehicle structure [1]. The functional block diagram as shown in Figure 1, illustrates the sequential order and the specific function of six primary blocks. The simulation blocks can be extensively made to order using the real-world vehicle specifications to ensure the precise results for an extensive range of electric vehicles available in the market.

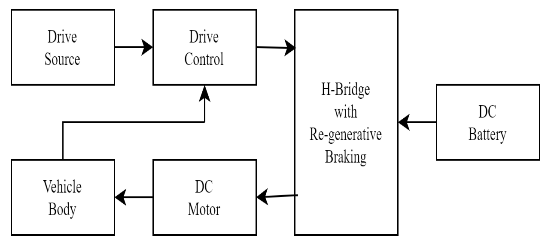


Fig. 1. Functional Block Diagram

Importing mechanical and aerodynamic parameters of the vehicle is necessary including tire slip, drag coefficient and friction. Due to certain proprietary restrictions, obtaining exact specifications for all aspects of the vehicle cannot be obtained. By comparing different properties of two different vehicles, the simulation will examine multiple aspects of interest related to the performance of each individual vehicle model. The simulation file contains physical and electrical signals that provide key information at different points within the electric vehicle analysis. Each vehicle model will be evaluated based on three key performance areas. The initial aspect examined is the reference velocity of the ideal driver cycle as it is a component of the vehicle model. By referring to the Simulink scope data, a comparison is produced to demonstrate the approximate velocity after considering the control and vehicle body components, the estimated velocity of every test car is determined [2]. The velocity of a vehicle is subject to change based on factors such as motor specifications, gearbox, reference signal and vehicle structure characteristics. The next point of focus involves implementing a Simulink scope to examine the acceleration data converted from reference driver source. The resulting data ranges from zero to one, which shows the precise rating of a driver's acceleration and braking responsiveness. The final aspect is to examine the comparison of total battery usage over the entire driving cycle. This data varies as a result of factors like the maximum battery capacity and the amount of energy consumption by the vehicle motor. By utilizing the scope results, it enables the visual interpretation that shows the independent vehicle performance revealing a comprehensive assessment of how this vehicle significantly affects their overall performance by the real-world parameters. This paper presents a distinct approach as it concentrates on the assessment and comparative analysis of two specific electric vehicle models available in the marketplace, rather than offering a comprehensive evaluation of simulation process [3], [4]. The selected vehicle models for comparison without any predetermined criteria are the Tata Nexon EV and BMW i4.

## II. Background

Electric vehicle modeling and simulation play a crucial part in design, analysis, and optimization of electric vehicles and their components. This involves creating mathematical and computational models which accurately represent the performance and efficiency of electric vehicles. Its development represents a significant investment for car manufacturers, who mostly rely on sophisticated software algorithms to create simulations that predict the performance of vehicles under specific test conditions. By distinguishing the simulations, manufacturers gain a deeper understanding of how their vehicle will perform and enable them to make up to date decisions and drive innovation in the electric vehicle industry.

## III. Modeling Flow

Fig. 2, illustrates the electric vehicle modeling flow chart [5]. The drive cycle source includes acceleration and braking input. The input to the longitudinal driver was feed using the output of the drive cycle source. The longitudinal driver has three inputs and three outputs. The three inputs are reference vehicle velocity, longitudinal vehicle velocity and road grade angle. The outputs are info that is bus signal, commanded vehicle acceleration and deceleration. Using a Simulink to physical signal converter, the output of longitudinal driver is given to the input of H-bridge and controlled PWM voltage. Five volt is set for activation of the pulse width and H-bridge is set as internally powered. DC battery is utilized to turn on the drivetrain that is motor of the vehicle. To provide the control action, the DC battery is connected to a power converter. The DC motor applied voltage can be changed using this converter. The axle of the wheels is connected with the electric motor. The vehicle framework includes headwind speed, velocity, hub, front axle normal force (NF), rear axle normal force (NR). The driver controller keeps track of the predicted velocity of the electric vehicle which then later tries to match it with the input of the drive cycle. It differentiates the reference velocity with the predicted velocity of the vehicle.

### A. Software Description

The application that we have made use of is MATLAB-Simulink and Simscape. It integrates the desktop environment for the design process and iterative analysis with programming language. Simscape enables the creation of physical systems quickly within the Simulink environment using direct integration with schematic diagrams and additional modeling

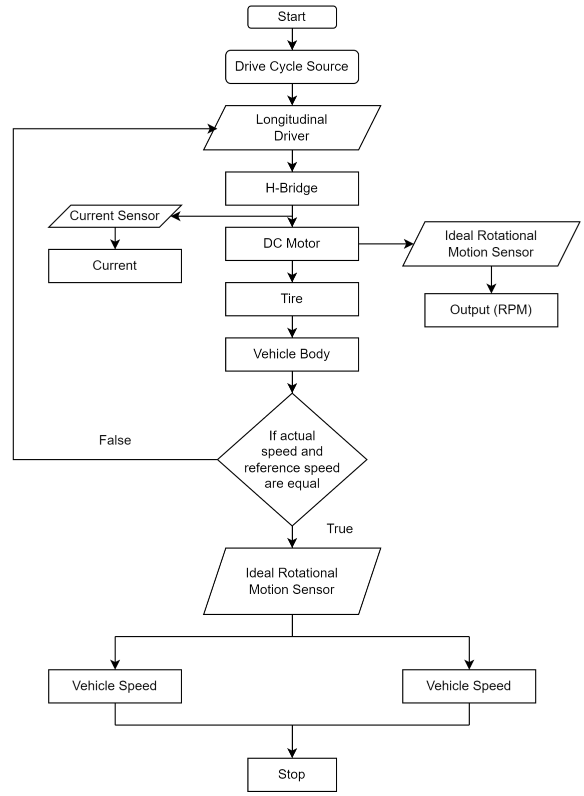


Fig. 2. Electric Vehicle Modeling Flow

prototypes. Assembling basic components into a schematic to design systems like electric machines, full wave rectifiers, hydraulic cylinders, and refrigeration frameworks. The Simscape additional products offer a wide range of complex components and improved analysis capabilities.

### B. Drive Cycle Source and Driver Controller

The drive cycle source generates a user defined or standardized longitudinal drive cycle. It includes the throttle input for acceleration and for the braking/deceleration purpose, brake pedal is used. The drive cycle source is used to provide the input reference to the drive controller. It compares the reference velocity with the actual velocity (feedback) of the vehicle and generates acceleration and deceleration commands.

### C. Power Converter and Battery

The H-bridge acts as a power converter. It has two simulation mode options: PWM and Averaged simulation mode. The output of H-bridge is a controlled voltage, and it depends on PWM port input signal. A DC battery is used to provide electric supply to the drive train and other components of the electric vehicle.

### D. DC Motor and Vehicle Body

The electric vehicle wheels are driven by using a DC motor which is powered by an DC battery. The motor has high initial torque which is best suited for various traction applications. These machines can easily resist high unexpected loads. The

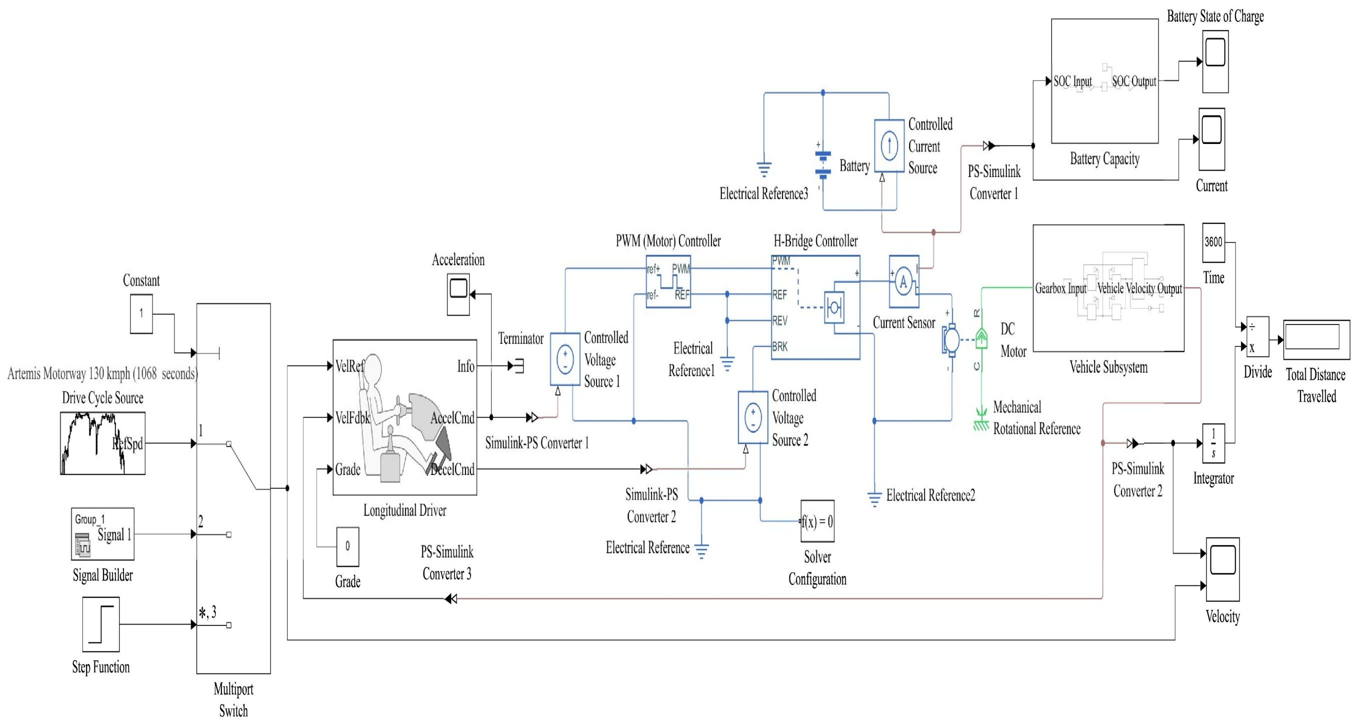


Fig. 3. Simulation Model of Electric Vehicle

vehicle body that has been utilized here is a two-axle vehicle body, and it has drag properties, a variable mass of the vehicle, road incline and road profile. Optionally, it has a pitch and dynamic suspension system.

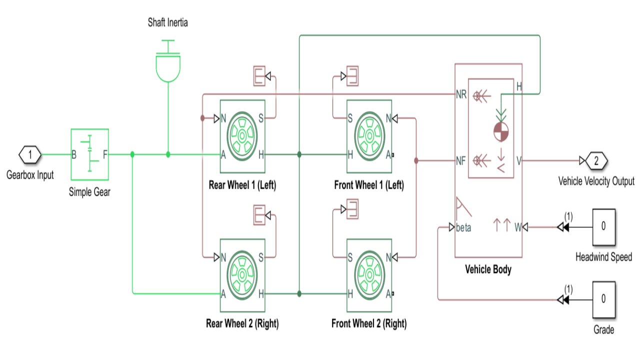


Fig. 4. Vehicle Body Subsystem

## *E. Parameter Implementation*

This section includes the chosen electric vehicle parameters for the simulation as shown in Table I [6], [7]. In order to simulate the electric vehicle's driving cycle, the Simulink model integrates the simulated velocity and the vehicle acceleration. Fig. 3, shows the simulation model of the electric vehicle. The design incorporates both the electrical and mechanical components in the model. The power converter transforms the energy from DC battery as required by DC motor drive train. The bidirectional converter allows regenerative energy to return back to the DC battery thus enabling charging of the battery when vehicle brake is applied, and it starts decelerating. The vehicle framework incorporates the main vehicle body along with the wheels which are coupled to the electric motor by means of a transmission system. The motor draws out the energy from the DC battery with the help of a regulator which generates controlling signals based on the load specifications. The controlling signals are generated by using the vehicle output feedback and the driving cycle is considered as a reference for driving the sequence of the vehicle simulation. Fig. 4, shows the electric vehicle framework with the drivetrain system simulation. It includes the vehicle body frame and the drive wheel configuration. Two wheels are employed at the front and rear of the vehicle.

TABLE I
ELECTRIC VEHICLE SIMULATION PARAMETERS

| **System Parameter** | **Tata Nexon EV** | **BMW i4** |
|---|---|---|
| **System Voltage** | 320 | 400 |
| **Battery Rating (Ah)** | 94 | 210 |
| **Drag Coefficient** | 0.15 | 0.24 |
| **Frontal Area** $(m^2)$ | 2.91 | 2.31 |
| **Gear Ratio** | 5.39 | 8.77 |
| **Configuration of Wheel** | All Wheel Drive | Rear Wheel Drive |
| **Motor Rated Speed (RPM)** | 3796 | 5000 |
| **Motor Rated Load (kW)** | 94 | 250 |
| **Mass (kg)** | 1400 | 2125 |

## IV. Simulation Results

The Tata Nexon EV and the BMW i4 each vehicle had their own merits and demerits. Due to various dissimilarities in vehicle such as motor rating, battery capacity and body design, there are significant difference in simulation results of both vehicles. The vehicle velocities, opening speed and the capacity of battery simulations rely on each other and their outcome will be affected by various individual parameters related to each different vehicle.

### A. Actual vs Reference Velocity Evaluation and Results

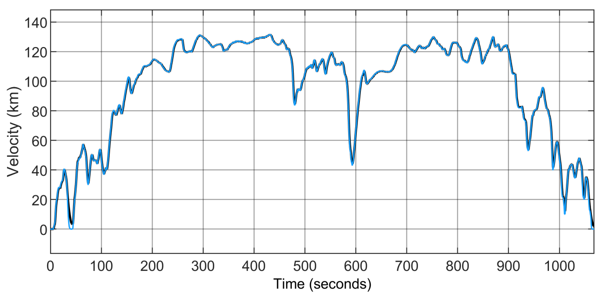


Fig. 5. Actual (black) versus Reference (blue) Velocity for BMW i4

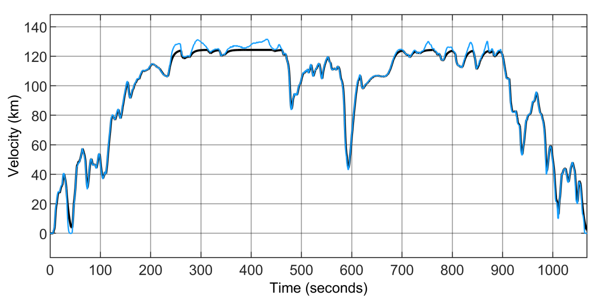


Fig. 6. Actual (black) versus Reference (blue) Velocity for Tata Nexon EV

Fig. 5 and 6 shows the simulation of two velocities of the vehicle, the reference velocity is represented by the blue color, and the estimated velocity is indicated by the black color. The driving cycle source that we have used is Artemis Motorway cycle. This cycle has two types of Motorways with maximum speed namely: 130 and 150 kilometers per hour. "The Common Artemis Driving Cycles (CADC) are chassis dynamometer procedures developed within the European Artemis (Assessment and Reliability of Transport Emission Models and Inventory Systems) project, based on statistical analysis of a large database of European real world driving patterns" [8]. By referring to the Figures 5 and 6, the scope results for Reference vs Actual Velocity, the visual differences between the Tata Nexon EV and BMW i4 model can be seen clearly. With the help of various parameters of simulation outlined in Table I, the BMW i4's specified motor with a load of 250 kW performs better than the Tata Nexon EV's 94 kW motor in nearly every aspect regarding velocity even though it has a higher mass of 2125 kg compared to Tata Nexon's EV. Another advantage of BMW i4's high performance motor is that it allows the vehicle to maintain the reference speed with accuracy beyond 100 kmph whereas the Tata Nexon EV is unable to follow the reference speed accurately. Other factors which affect the velocities of the vehicle is the different values of gearbox configurations and motor power specifications. As the BMW i4 has higher rating motor, it facilitates the vehicle to retain the output power closely to the optimal rate.

### B. Vehicle Acceleration Evaluation and Results

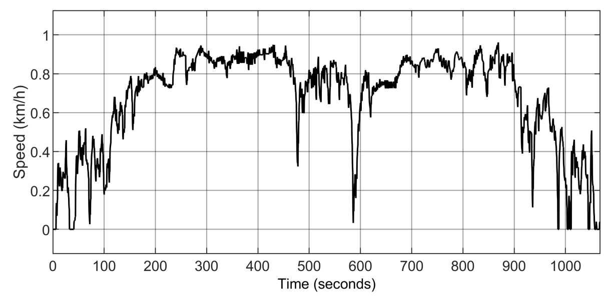


Fig. 7. Time versus Acceleration and Braking for BMW i4

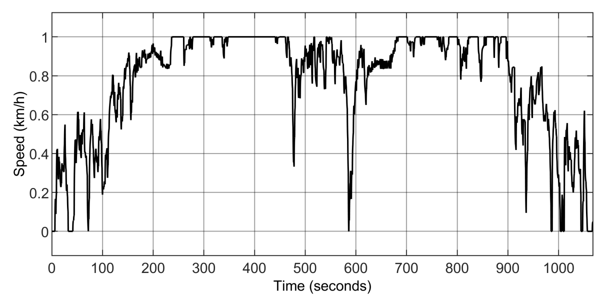


Fig. 8. Time versus Acceleration and Braking for Tata Nexon EV

The visual representation of the reference velocities of Longitudinal Driver acceleration and braking is shown in Figures 7 and 8. The line shows the acceleration specific to each individual vehicle. The variation in the acceleration is similar to the vehicle parameters which had greater influence on each vehicle's overall velocity. The driver's acceleration in the source drive cycle reaches to a certain limit at high velocity due to the Tata Nexon EV motor's maximum power output. The BMW i4 has a higher top speed and quick acceleration towards the required reference velocity leading to improve overall outcome.

### C. Battery Capacity Evaluation and Results

The last assessment shows the total battery capacity consumed during the 1068 seconds drive cycle as shown in Figures 9 and 10, respectively. The battery capacity corresponding to each individual vehicle model is set to 100 percent at the start of 0 second drive cycle duration, and it will start discharging by supplying the battery energy to the power converter and the drivetrain as it tries to match the velocity of vehicle with the drive cycle source reference velocity. With the help of the regenerative braking system, the discharged battery energy is restored during the entire duration of the drive cycle simulation. The particular factors of the drive profile implemented for each individual vehicle model will strongly affect the discharging of the battery and the regenerative braking properties of the graph. With both the vehicle batteries starting at full capacity of the drive cycle source, the overall power consumption of the vehicle batteries was mostly related to the individual vehicle parameters. The BMW i4 has a large battery with a total capacity of 210 Ah, and it was able to preserve most of the charge even though it has extra eighty volts powering to the vehicle motor. In overall simulation, the BMW i4 model ended with approximately 89 percent of charge at the end. The regenerative braking moreover had a minor effect on the battery's capacity due to the motor functioning as a generator while decelerating which increased the total battery capacity by 1 to 2 percent at the final stage of the drive cycle. The Tata Nexon EV had a lesser impact of regenerative braking which results in a higher depletion of its 94 Ampere-hour (Ah) battery capacity. In the last stage of the drive cycle source, the charge retained by the Tata Nexon EV was around 81 percent, verifying the benefits of a high-capacity battery of the electric vehicle on the total distance traveled during a drive.

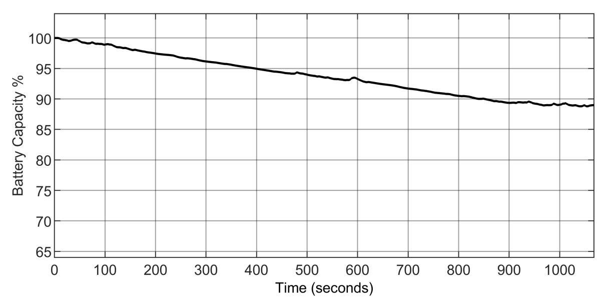


Fig. 9. Time versus Battery Capacity for BMW i4

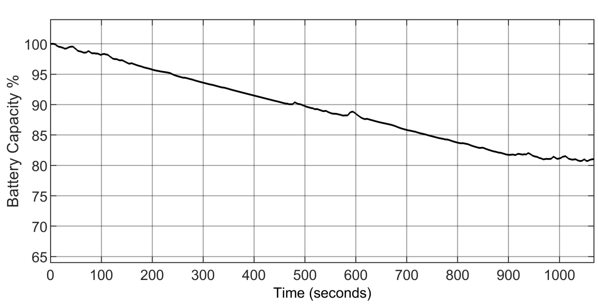


Fig. 10. Time versus Battery Capacity for Tata Nexon EV

### D. Known Inaccuracies

Following are some known inaccuracies exist in the simulation, primarily due to certain exclusions [9].

- Performance of the vehicle and brake dimensions
- Frictional and the transmission losses
- Tire dimensions, width, and grip
- Aerodynamics of the vehicle
- Power converter and motor losses
- Lithium-ion cell specifications
- No-load speed of the DC motor
- Center of gravity distance from the front and rear axle
- Aspects of regenerative braking
- Real world road profiles.

## V. Conclusion

Using the MATLAB Simulink, the comparative analysis of the electric vehicle was illustrated. With the help of the reference velocity profiles and its comparison, one can effectively predict and measure the performance of electric vehicles in the real-world scenarios. Factors like motor rating, battery capacity, system voltage play a crucial role in finding the electric vehicle's performance. Because of the powerful motor of BMW i4, it outperforms the Tata Nexon EV in almost all the aspects. To improve the model, we can include the losses which occur throughout the simulation process of the vehicle and add a complex array of libraries to improve the functionality. As electric vehicles are dominating the vehicular market, new and improved models of electric vehicles are coming to the market every year. The simulated analysis of vehicles with the relative performance, will provide further details to buyers into the process of engineering. The methods proposed in this paper gives quite simple and effective way for buyers to compare electric vehicles which best suit their needs accordingly.

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