



A longitudinal dynamic simulation model is developed for a battery electric vehicle (BEV) with a centralized single-motor drive system to enable performance analysis and optimization

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ABSTRACT

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This study aims to model and simulate the longitudinal dynamics of a fully electric vehicle to support battery pack design and evaluate performance and driving range under standard driving cycles. Simulations were conducted in MATLAB-Simulink, using two approaches: (1) A mathematical model that strictly follows the target speed profile; (2) A longitudinal dynamic model simulating driver behavior in response to driving cycles. The first approach estimated energy consumption for completing a cycle, which was then used in a backward simulation to calibrate a PID controller representing the driver and to design and validate the battery pack. The backward model also assessed vehicle range and performance, providing key battery parameters such as temperature, current, and state of charge (SOC). Special focus was placed on modeling the battery pack, incorporating a thermal model and open-circuit voltage (OCV) characteristics relative to depth of discharge (DoD). The thermal model calculated battery temperature based on dissipated power and applies torque derating control to ensure safe operation.

1. INTRODUCTION

The shift toward electric vehicles (EVs) is revolutionizing the global automotive industry,

driven by the need for environmental sustainability and renewable energy use. As transportation demands grow, internal

combustion engine (ICE) vehicles are contributing to urban pollution and health risks, urging a transition to cleaner solutions. EVs offer impressive benefits, including high efficiency (70-98%), reduced noise, and lower emissions. Vietnam, aligning with this global movement, is actively investing in EV research and development to replace ICE vehicles gradually. The EV market includes categories like Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs), Hybrid Electric Vehicles (HEVs), and Fuel Cell Electric Vehicles (FCEVs), each addressing various energy and emission needs. BEVs, offering zero emissions and simplicity, are becoming a primary focus for manufacturers, underscoring the industry's dedication to sustainable transportation.

2. MATERIALS AND METHOD

2.1 Set up a model for studying the longitudinal dynamics of a Battery Electric Car (BEC)

2.1.1 The powertrain of a Battery Electric Vehicle (BEV)

This study outlines the development of a basic model for analyzing the longitudinal dynamics of Battery Electric Vehicles (BEVs), focusing on constructing a mathematical model and applying simplifying assumptions. This process emphasized algorithm selection for efficiency and practicality while avoiding unnecessary complexity. Electricity, replacing fossil fuels as the primary energy source, powers BEVs entirely through onboard batteries charged from the grid and supported by regenerative braking. This marked a significant step toward cleaner and more sustainable transportation (Othaganont et al., 2017).

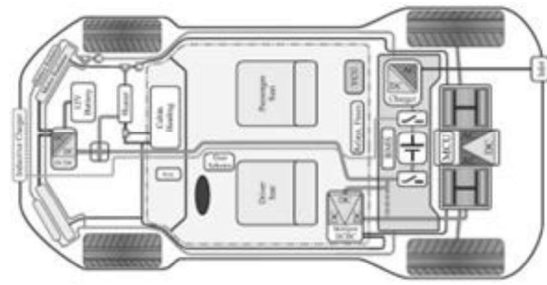


Figure 1. Topology of BEV

2.1.2 The powertrains of BEVs can be classified based on their motor configuration and drivetrain design

- Electric vehicles (EVs) employed diverse powertrain topologies to meet specific performance and operational demands. Two fundamental configurations were analyzed:

+ Single-Motor Single-Axle (SM-SA): A single motor was used to drive either the front or rear axle. This configuration offered simplicity and cost efficiency and was commonly adopted in lightweight or entry-level electric vehicles (EVs).

+ Dual-Motor Dual-Axle (DM-DA): Each axle was powered by an independent motor, enabling all-wheel drive (AWD), improved traction, and enhanced dynamic performance—ideal for high-performance or off-road applications.

- Further configurations included:

+ In-Wheel Motor Single-Axle (IWM-SA): Motors were integrated into the wheels of one axle, eliminating the central drivetrain. This compact and lightweight design suits urban or compact EVs.

+ In-Wheel Motor Dual-Axle (IWM-DA): Motors in all four wheels provided AWD, precise torque vectoring, and superior handling, optimized for performance and off-road vehicles.

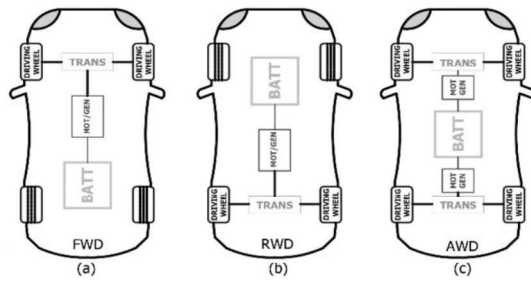


Figure 2. The Central Drive architecture

2.2 Developing a mathematical model for a Battery Electric Car (BEC)

This section outlined a schematic model of a Battery Electric Vehicle (BEV) and presented a preliminary analysis of its performance and range under standard driving cycles. It also provided input data on energy consumption for the longitudinal dynamic model. The applied algorithms were based on vehicle dynamic behavior, translated into battery parameters to meet performance targets. Model development was carried out in the MATLAB environment, with further details provided in the subsequent section.

2.2.1 The structure of the model

The model consisted of two core subsystems: mechanical and electrical (Park et al., 2014). The mechanical subsystem utilized vehicle and motor parameters, combined with speed profiles and dynamic equations, to compute outputs such as power demand, tractive force, and vehicle acceleration. The electrical subsystem processes battery and motor specifications, integrated feedback from the mechanical model, and simulates energy flow and control logic.

A typical BEV powertrain integrated both domains to ensure efficient propulsion. The electrical system included a battery pack, DC-AC inverter, DC-DC converter, electronic controller, and an Interior Permanent Magnet Synchronous Motor (IPMSM). Driver inputs were converted

into speed profiles, regulated by a PID controller to generate torque and speed commands. The controller modulated inverter signals to control motor output, which is transmitted to the mechanical drivetrain.

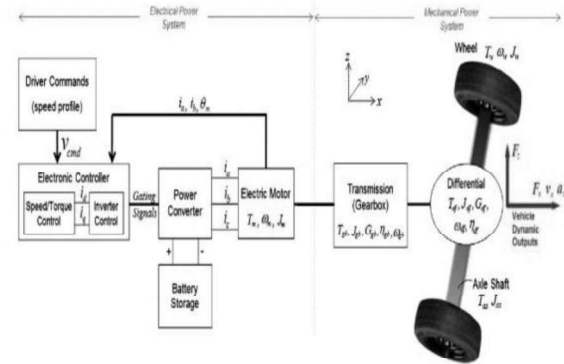


Figure 3. Conventional BEV Powertrain

The mechanical system comprised the transmission, differential, axle shafts, and wheels. It delivered dynamic responses such as tractive force (F_x), vertical load (F_z), vehicle speed (v_x), and acceleration (a_x), which were critical for evaluating vehicle performance across various driving conditions.

2.2.2 The longitudinal vehicle dynamics model

The required power for vehicle motion P_n was evaluated using the following equation. (Abe, 2015; Genta and Morello, 2020).

$$P_n = F_r \cdot v_x + m_{eq} \frac{dv_x}{dt} v_x = F_n v_x = \frac{T_w \cdot v_x}{r_e} \quad (1)$$

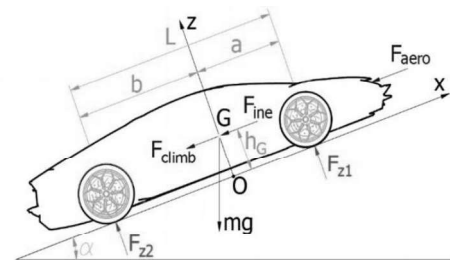


Figure 4. Conventional BEV Powertrain

Where F_r is the sum of all resistance forces; v_x is the vehicle speed. $F_n = F_r + F_{ine} = F_{climb} + F_{aero} + F_{rol} + F_{ine}$ is the needed traction force for

motion of vehicle; m_{eq} is the equivalent mass of vehicle.

* *Climbing force:* $F_{climb} = m.g.\sin(\alpha)$ (2)

* *Aerodynamic drag resistance force:*

$$F_{aero} = \frac{1}{2} \rho . v_x^2 . c_x . S_a \quad (3)$$

* *The rolling resistance force:* Rolling resistance arises from tire deformation against a rigid road surface. As the tire compresses and recovers during motion, energy was dissipated, reducing overall vehicle efficiency.

The rolling resistance force was measured experimentally in laboratories by simulating real-world conditions.

$$F_{rol} = m.g.\cos(\alpha) [f_0 + K v_x^2] \quad (4)$$

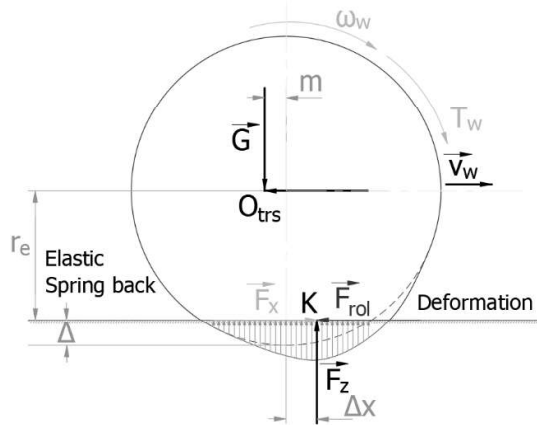


Figure 5. Tire deformation

Where f_0 and K are the static and dynamic rolling resistance, respectively. The rolling resistance diagram (Fig.6) illustrates two key coefficients. The first represents the static behavior, which remains nearly constant at low speeds below a critical threshold. The second coefficient describes the quadratic increase in rolling resistance as the speed surpasses the critical value, highlighting the significant impact of velocity on resistance. For a light vehicle, typically values were: $f_0 = 0.015$; $K = 7.10^{-6} \text{ s}^2/\text{m}^2$.

To summarize, the resistance forces discussed can be ordered based on their dependency on the vehicle's speed as follows (Genta, 1997):

$$F_r = A + B.v_x^2 \quad (5)$$

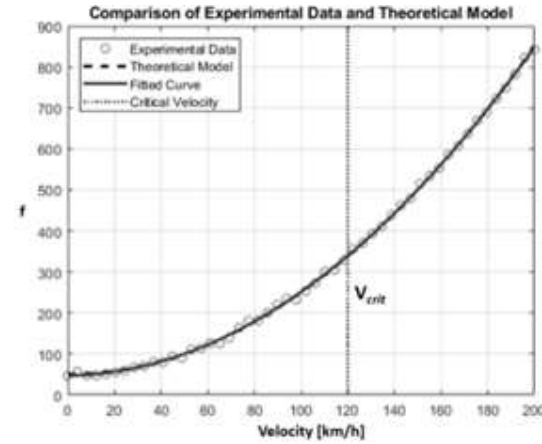


Figure 6. Experimental and theoretical model comparison

Where A and B were respectively static and dynamic contributions

$$\begin{cases} A = m.g [f_0 \cos \alpha + \sin \alpha] \\ B = m.g.K.\cos \alpha + \frac{1}{2} \rho.c_x.S \end{cases} \quad (6)$$

* *The inertia force:*

The second term in equation (1) represented inertial forces, reflecting the vehicle's resistance to acceleration. These forces were defined as follows:

$$F_{ine} = m_{eq} \frac{dv_x}{dt} \quad (7)$$

$$m_{eq} = m + \frac{4.J_w}{r_e^2} + \frac{J_m.i^2}{r_e^2} \quad (8)$$

For a pneumatic tire an effective rolling radius r_e can be defined as the ratio vehicle speed v_x and the tire angular speed ω_w

$$r_e = \frac{v_x}{\omega_w} \quad (9)$$

As shown in the below (Fig.4), the effective rolling was bigger than the loaded radius and

smaller than the unloaded radius: $r_l < r_e < r$. In case the wheels roll completely, and no slip occurs, the effective rolling radius was equal to the dynamic radius: $r_l = r_d$.

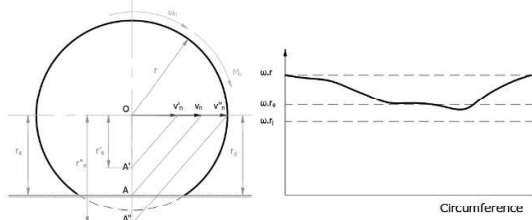


Figure 7. The effective rolling radius

* Power at battery level (Power request)

By multiplying equation (1) with the efficiencies of the system components, it is possible to calculate the power required at the battery level for each moment of the speed profile (Wang et al., 2017; Gupta, 2013).

$$P_b = \eta_t \cdot \eta_m \cdot \eta_b \cdot P_n \quad (10)$$

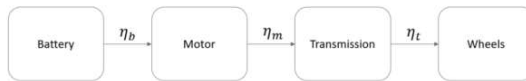


Figure 8. Drivetrain layout

Where P_b is the battery power, η_t , η_m , η_b are respectively the transmission, motor-inverter and battery efficiency.

*Acceleration (Performance): The power available to accelerate the vehicle was derived from the following equation (7)

$$P_{wh} - P_n = \frac{dT_{kinetic}}{dt} \quad (11)$$

The right term of equation (11) represent the instantaneous variation of the kinetic energy in time.

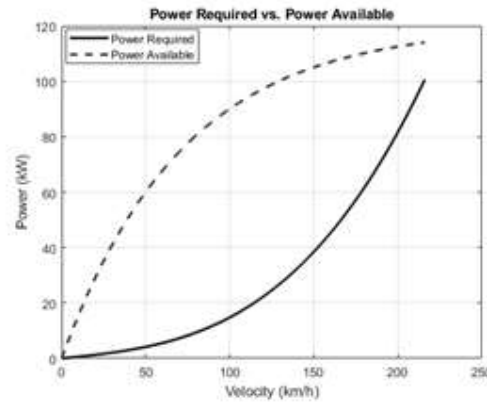


Figure 9. Power needed to motion and power available

$$T_{kinetic} = \frac{1}{2} m_{eq} \cdot v_x^2 \quad (12)$$

By substituting equation (12) into equation (11), the maximum achievable acceleration can be determined (Equation 13).

$$a_{max} = \frac{P_{wh} - P_n}{m_{eq} \cdot v_x} \quad (13)$$

From equation (13), where acceleration is defined as $\frac{dv_x}{dt}$, the time required to accelerate between two velocities can be calculated (Equation 14)

$$t_{v_1 \rightarrow v_2} = \int_{v_1}^{v_2} \frac{m_{eq} \cdot v}{P_{wh} - P_n} dv = \int_{v_1}^{v_2} \frac{1}{a_{x_{max}}} dv_x \quad (14)$$

* The vertical force: The model supported three drivetrain configurations: Front-Wheel Drive (FWD), Rear-Wheel Drive (RWD), and All-Wheel Drive (AWD), allowing flexible selection based on vehicle layout.

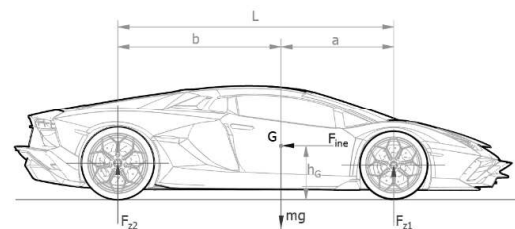


Figure 10. Front-wheel vehicle load shift layout

Front wheel drive (FWD):

$$F_{z1} = m \left(g \frac{b}{L} - \frac{dv_x}{dt} \frac{h_G}{L} \right) \quad (15)$$

Rear wheel drive (RWD):

$$F_{z2} = m \left(g \frac{a}{L} + \frac{dv_x}{dt} \frac{h_G}{L} \right) \quad (16)$$

$$\text{All wheel drive (AWD): } F_z = m.g \quad (17)$$

2.2.3 The electrical model

The model of IPMSM is shown in Fig.10. The ABC , $\alpha\beta$ and dq frames represent the natural, the stationary, and the rotating reference frames, respectively. The mathematic model of IPMSM in stationary reference frame was expressed as

$$u_\alpha = R.i_\alpha + L_d \frac{di_\alpha}{dt} + \omega_e \cdot (L_d - L_q) i_\beta + e_\alpha \quad (18)$$

$$u_\beta = R.i_\beta + L_q \frac{di_\beta}{dt} + \omega_e \cdot (L_d - L_q) i_\alpha + e_\beta \quad (19)$$

Where u_α , u_β are stator voltage; i_α , i_β are stator currents; R is stator resistance; ω_e is electrical rotor speed; L_d , L_q are stator inductances; e_α , e_β are the $\alpha\beta$ -axis back EMFs of IPMSM, satisfying $e_\alpha = -E \cdot \sin \theta$ and $e_\beta = -E \cdot \cos \theta$; θ is the rotor position. With ψ_f is PM flux linkage; E is the amplitude of back EMF (Genta & Morello, 2009; Chen, 2003)

$$E = (L_d - L_q) \left(\omega_e \cdot i_d - \frac{di_q}{dt} \right) + \omega_e \cdot \psi_f \quad (20)$$

* **Battery pack model:** The BEV utilizes a battery pack composed of cylindrical cells arranged in series-parallel configurations. For example, two

parallel rows of 12 cells yielded a 24-cell pack, as shown in Fig.11.

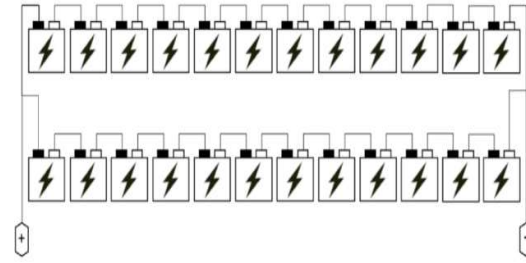


Figure 11. Scheme of a battery layout with 24 cells

The Equivalent Circuit Model (ECM) characterizes battery behavior through the Open Circuit Voltage (OCV), which was highest at full charge and decreases during discharge. Each cell follows a distinct OCV curve, as illustrated in Fig.12.

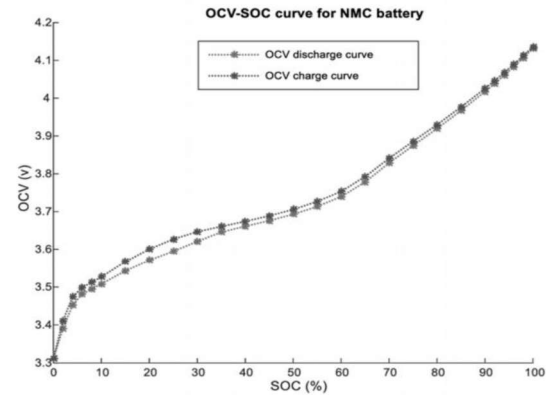


Figure 12. OCV – SOC curve for NMC battery

It is clear to note that when the cell was fully charged had a voltage of 4.2V, then steeply decreased to 4.0V for a DOD of about 5%, then in a range of 5% to 95% the OCV had a linear characteristic that can bring the voltage from 4.0V to 3.4V. Finally, the OCV dropped to 2.7V for DOD that were approaching the 100% value.

* **Thermal model:** Lithium-ion batteries operated optimally within a temperature range of 20°C to 30°C, though they can function between - 40°C and 60°C. Higher operating temperatures accelerated the battery's aging process, and

excessive heat (above 80°C to 100°C) can lead to thermal instability of the cell's active materials, potentially compromising safety and performance.

The analytical scheme of the 2nd order system was the following:

$$\Delta T = P_{dis} \left(\frac{1}{\frac{1}{R_{ch1}} + C_{ch1} \frac{dP_{dis}}{dt}} + \frac{1}{\frac{1}{R_{ch2}} + C_{ch2} \frac{dP_{dis}}{dt}} \right)$$

Writing the variables in this manner:

$$\begin{cases} \Delta T(t) = Y(s) \\ P_{dis}(t) = X(s) \end{cases}$$

Where (s) represents the Laplace variable, the

$$\text{Transfer Function will be: } G(s) = \frac{Y(s)}{X(s)} \quad (21)$$

The transfer function in the Laplace domain was so written:

$$G(s) = \frac{R_1}{1 + \tau_1 \cdot s} + \frac{R_2}{1 + \tau_2 \cdot s} \quad (22)$$

***De-rating control:** A saturation control mechanism regulated battery current to prevent overheating and inefficiencies under extreme temperatures. At high temperatures, it limited current to reduce power dissipation; at low temperatures, it restricted flow to avoid energy buildup due to elevated electrochemical resistance.

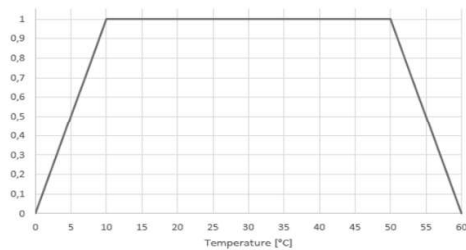


Figure 13. Thermal battery saturation's coefficient

The system used a temperature-dependent look-up table (Fig.13) assigning a coefficient from 0 to 1. Current was scaled by this coefficient: Below 10°C or above 50°C → coefficient < 1 → current reduced; Between 10°C and 50°C → coefficient = 1 → current unchanged.

This control prevented overcurrent during traction (e.g., +300 A) and braking (e.g., -100 A), protecting cells from thermal stress and degradation. The model processed input current and outputs battery temperature and de-rated current, enabling safe and efficient battery operation.

***Energy consumption:** The battery model's final output calculated the vehicle's energy consumption during driving cycles by integrating the power required for motion at the battery level, as explained in formula (24).

$$E_b = \frac{1}{3600} \int P_b \cdot dt; E_{cons} = \frac{E_b}{d/100}; \quad (23)$$

$$\int P_b \cdot dt = \left(\int_{traction} P_{b-out}(t) \cdot dt - \int_{braking} P_{b-in}(t) \cdot dt \right) \quad (24)$$

$$P_{b-out} = \frac{F_r \cdot V_{car}}{\eta_{pow}}; P_{b-in} = \alpha \cdot P_{regen} \quad (25)$$

Where η_{pow} is powertrain efficiency (including battery, electric motor and transmission), γ is the percentage of the braking energy that can be recovered ($0 < \gamma < 1$), is also called regenerative braking factor and P_{regen} .

Knowing the battery energy and the energy need to finish the driving cycles was possible to evaluate the vehicle range (Makarchuk et al., 2015)

$$\text{Range} = \frac{E_b}{E_{\text{cycle}}} \text{length}_{\text{cycle}} \quad (26)$$

For instance, the standard cycle length was 11 km for NEDC and 23.25 km for WLTP.

2.3 The investigation of longitudinal dynamics in electric cars

2.3.1 Build a survey program

This study developed core block models for the drivetrain, vehicle body, and electrical systems to simulate the longitudinal dynamics. These components are integrated via signal lines to reflect real-world transmission architecture, forming a complete simulation model based on prior mathematical formulations (Fig.14).

Analyzes vehicle performance and driving range under various driving cycles and battery control parameters, including current amplitude, state of charge, and pack temperature.

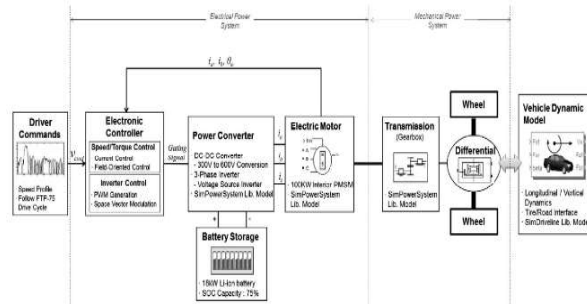


Figure 14. Initial BEV configuration in MATLAB model

2.3.2 The overview of model

The model applied two approaches: one estimated energy consumption based on SOC during standard drive cycles; the other evaluated range, performance, and battery parameters (voltage, current, SOC). Built in MATLAB/Simulink, it used inputs such as drive cycles, vehicle specifications, motor efficiency, and battery data.

The vehicle was partitioned into modular blocks, including the Vehicle Control Unit (VCU), vehicle dynamics, motor, and battery. A reference driving cycle was compared to actual speed via a feedback loop. The PID controller processed this difference into a torque request, which drives the motor and adjusts vehicle speed accordingly. Motor and battery blocks exchanged power commands to maintain energy balance. Motor torque was converted into vehicle motion, ensuring synchronized operation and accurate performance tracking.

2.3.3 Vehicle Block

The motor block provided torque as an input to the vehicle block, which outputs the vehicle's actual speed as feedback. The internal structure, as depicted in the accompanying diagram, consisted of three main sections: the first represented the wheel mechanics, the second consolidated the dynamic equations governing motion, and the third calculates the distance traveled. This systematic design supported accurate modeling of vehicle performance.

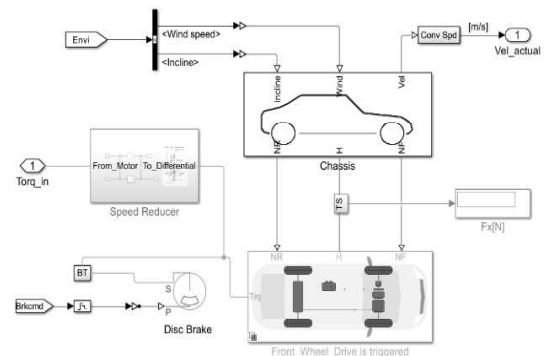


Figure 15. Longitudinal vehicle dynamics model in simulink

2.3.4 Speed reducer

This type of electric vehicle was typically outfitted with a single-speed transmission. This section only simulated speed reducer, about differential will be shown in drive configuration.

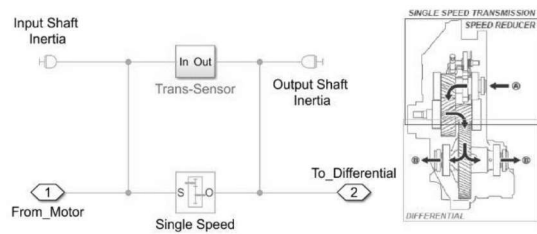


Figure 16. A speed reducer model

2.3.5 Tire model

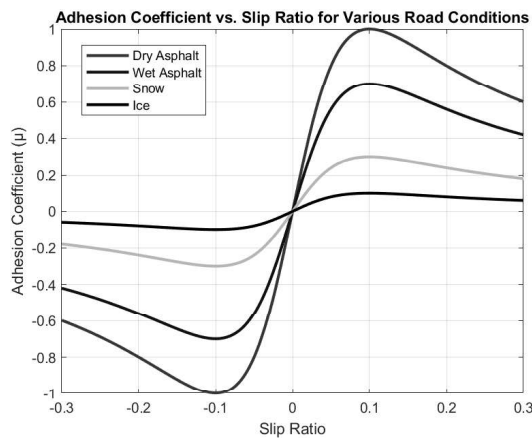


Figure 17. Adhesion coefficient vs. slip ratio under different road conditions

The tire produced essential driving forces at the road interface-traction during acceleration and braking during deceleration-enabling effective propulsion and speed control.

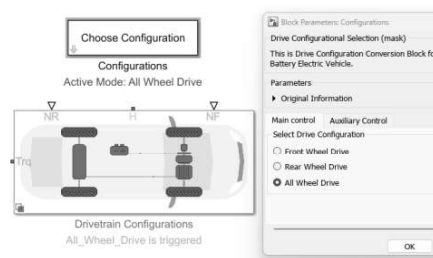
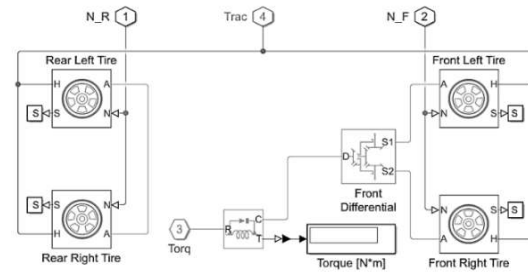


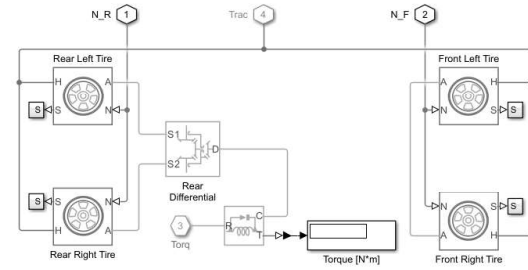
Figure 18. Select the drive configuration

2.3.6 Drive configuration

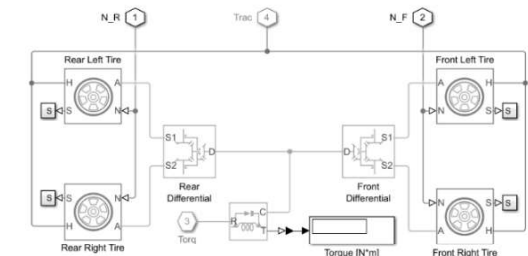
The model allows for selecting different drive configurations (Fig.19) including All-Wheel Drive (AWD), Front-Wheel Drive (FWD), and Rear-Wheel Drive (RWD). It was designed to simulate the dynamic behavior of any electric vehicle. However, this article focused specifically on the Front-Wheel Drive (FWD) configuration.



a. Front Wheel Drive (FWD)



b. Rear Wheel Drive (RWD)



c. All Wheel Drive (AWD)

Figure 19. Drive configuration

2.3.7 Electric motor block

In early EV development, motor performance targets and efficiency were defined based on system architecture and design objectives. For IPMSM simulation, tools like Ansys Motor-CAD were used. As illustrated in Fig.20, parameters from the Nissan Leaf motor can be applied for accurate modeling.

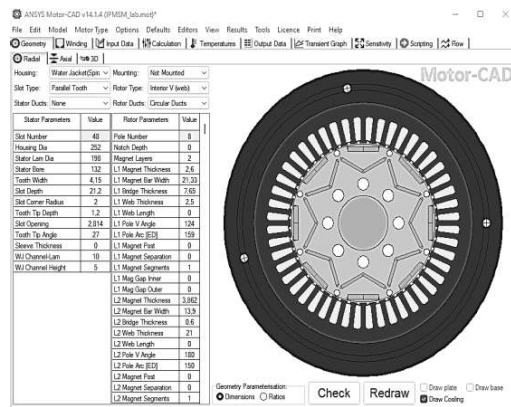


Figure 20. Design of IPMSM by Ansys Motor CAD

The battery connected to a voltage inverter that drove a variable voltage and frequency motor, controlled via Field Oriented Control (FOC). As shown in Fig.21, the battery block receives actual vehicle speed and torque request (via PID from the VCU), processes power and SOC, and outputs electric power and torque to the

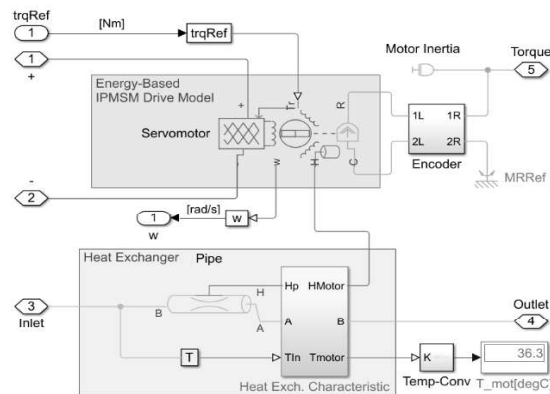


Figure 21. Electric motor in simulink environment

vehicle block.

2.3.8 Battery block

Battery blocks were formed by combining multiple cells. A key design element is the thermal management system (Fig. 22), which maintains stable temperatures to improve efficiency and optimize charge-discharge performance.

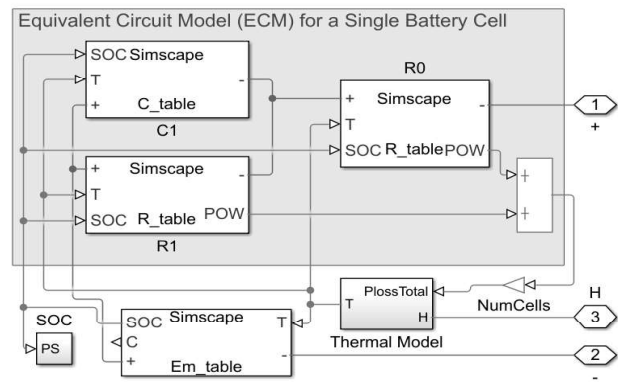


Figure 22. Electric and thermal model of battery

2.3.9 Vehicle control unit block

The Vehicle Control Unit (VCU) manages EV operations, similar to an ECU in conventional vehicles. It receives actual and reference speeds derived from driving cycles (Fig.23)-and uses a PID controller to generate torque commands (Figs .24, 25).

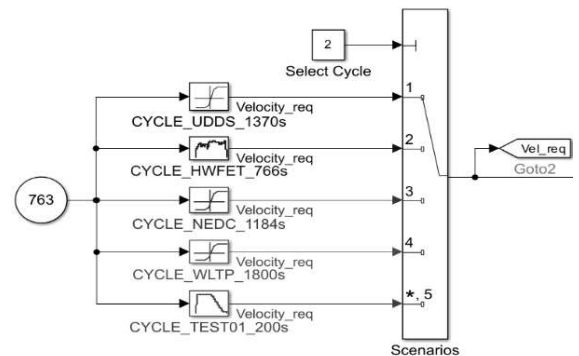


Figure 23. Choose driving cycles

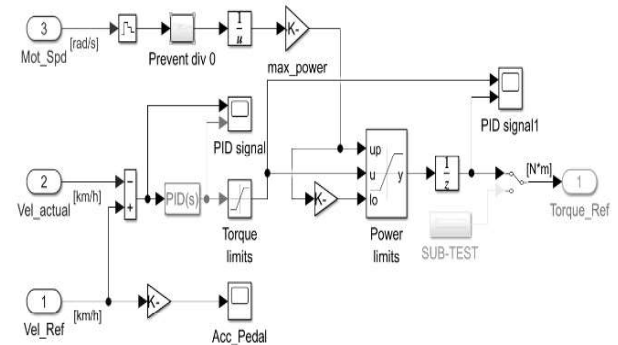


Figure 24. PID controller

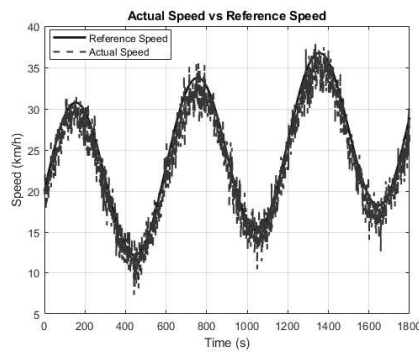


Figure 25. WLTP actual speed vs reference speed

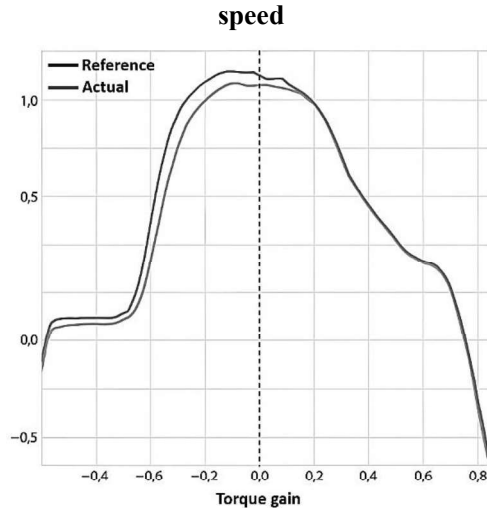


Figure 26. WLTP speed comparison

Continuous comparison of actual vs. reference speed (Fig. 25) enables precise control. Speed deviations (Fig. 26) are processed by the PID controller to simulate driver behavior and adjust torque, ensuring accurate and efficient performance tracking.

3. RESULTS AND DISCUSSION

3.1 Surveying longitudinal dynamics

3.1.1 BEV simulation model for longitudinal dynamics verification

A one-motor Battery Electric Vehicle (BEV) model was developed in MATLAB-Simulink to validate the theoretical dynamics derived earlier. The model incorporated component libraries and experimental parameters, focusing on front-wheel drive configuration.

+ Inputs: Speed reference, terrain slope (excluding auxiliary power losses)

+ Outputs: Vehicle linear speed, motor rotational speed, electric/mechanical torque, rotor currents, battery state of charge. Vehicle performance was evaluated using standardized driving cycles-NEDC and WLTP-to simulate real-world speed-time profiles for assessing energy consumption and dynamic response.

The NEDC, introduced by the EU in 1992, standardizes fuel consumption testing for passenger and light commercial vehicles under controlled conditions. The WLTP, adopted globally since September 2017, offers more dynamic and realistic testing parameters to better reflect actual driving behavior and energy usage.

3.1.2 Simulating a BEV model with parameters as Tables 1-4

Table 1. Parameters of vehicular body

Parameters of vehicular body	Value
Mass of vehicle	1,490 (kg)
a	1.4 (m)
b	1.6 (m)
h_G	0.5 (m)
Front area	2.5 (m ²)
Drag coefficient	0.4

Table 2. Parameters of tire

Parameters of tire	Value
r_e	0.315 (m)
F_z	3,000 (N)
f_0	0.015
K	7.10^{-6} (s ² /m ²)

Table 3. Specification of motor and battery

Specification of motor	Value
Max speed	10,000 (rpm)
Max power	80 (kW)

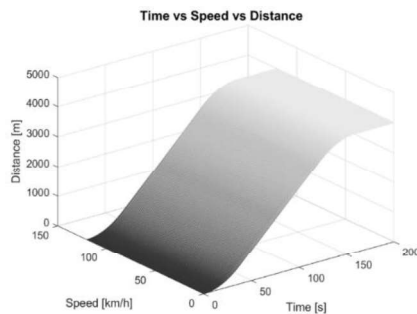
Max torque	253 (Nm)
Battery storage	24 (kWh)

Table 4. NEDC and WLTP Cycles Results

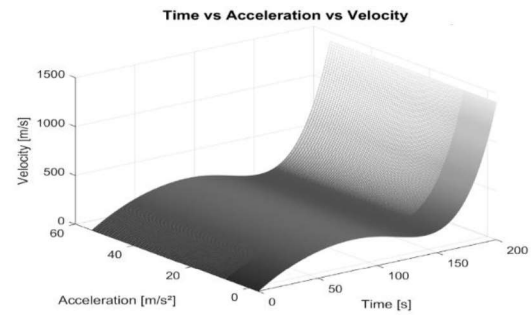
	Unit	NEDC	WLTP
Time	s	1,180	1,800
Distance	km	11	23.25
Range	km	174.72	152.71
SOC	%	89.1	87.8
Energy consumption	$\frac{\text{kWh}}{100\text{km}}$	13.89	15.77
Regenerative braking gain	$\frac{\text{kWh}}{100\text{km}}$	1.21	1.34

3.2 Results

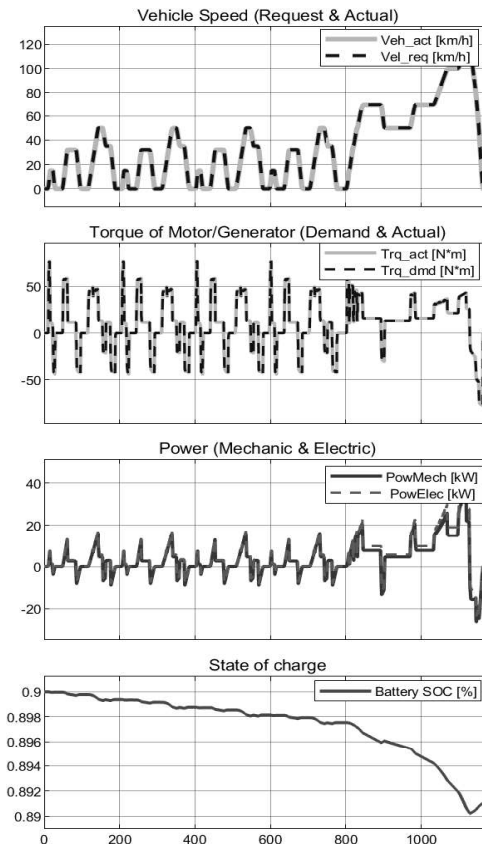
In this work, the type of BEV included in the survey was the Nissan Leaf, which parameters were given by the manufacturer as shown in Nissan Leaf – Advanced Vehicle Testing – Baseline Testing Results (2013). Acceleration 0-60 mph (approximately 96 km/h) with measured time: 10.6 s; Maximum speed 77.5 mph (about 125 km/h).

**Figure 27. Time vs Speed vs**

The survey results in Fig.28 are quite close to the parameters given by the manufacturer. The car reaches a speed of 100 km/h at time $t=11.5\text{s}$ and the maximum speed of the car is 128 km/h at $t=23\text{s}$. Also at this time the acceleration is almost zero as shown in Fig. 29, the vehicle reaches top speed.

**Figure 28. Time vs Acceleration vs Velocity**

According to the simulation results including NEDC and WLTP cycles, it was understood that vehicle speed and cycle speed were the same. At this point, it is concluded that the energy consumption data obtained from the model is also correct.

**Figure 29. The results with NEDC cycle**

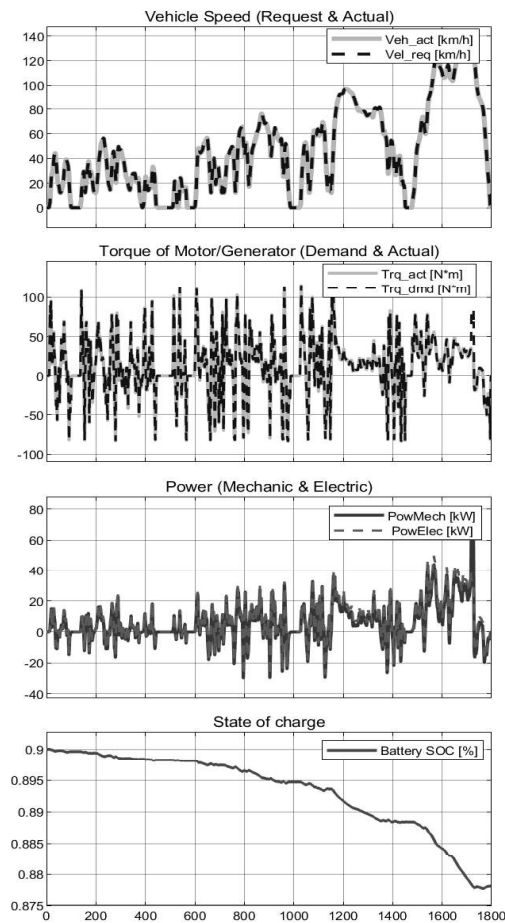


Figure 30. The results with WLTC cycle

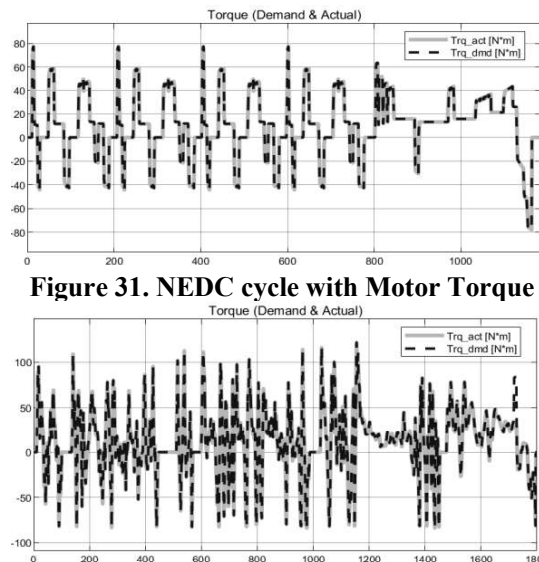


Figure 31. NEDC cycle with Motor Torque

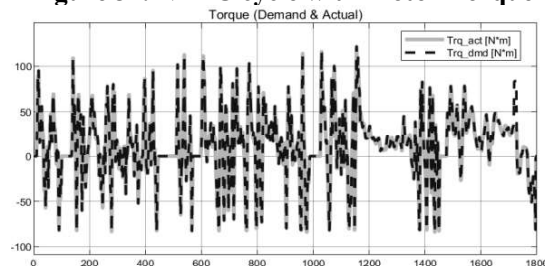


Figure 32. WLTP cycle with Motor Torque

NEDC and WLTP calculations can be seen in the table. These values allow comparison of the modeled vehicle with other vehicles.

The BEV Matlab model demonstrated a fully charged range of 177.7 km with energy consumption of 13.8 kWh per 100 km for the NEDC cycle, and a range of 157.7 km with 15.49 kWh per 100 km for the WLTP cycle. Regenerative braking achieved around 8% energy savings in both driving cycles. Additionally, results from NEDC and WLTP cycles, as shown in Figs.31-32, indicate a strong consistency between demanded and actual torque values, with negligible deviations, ensuring the simulation process's accuracy. Hence, the mechanical power and electrical power were also almost identical and the deviation was negligible (less than 5%). Thus, the engine's maximum efficiency (more than 95%) was completely consistent.

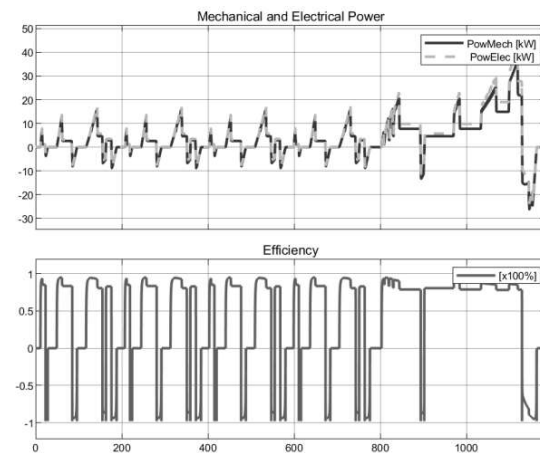


Figure 33. NEDC cycle with Power and Efficiency

When the vehicle decelerates according to the driving cycles as shown in Figs.29-30, the SOC graph increases, in the graph there are many ripples. These ripples represent regenerative braking. During discharge, the battery capacity does not increase significantly but contributes to an increase in the vehicle's operating range.

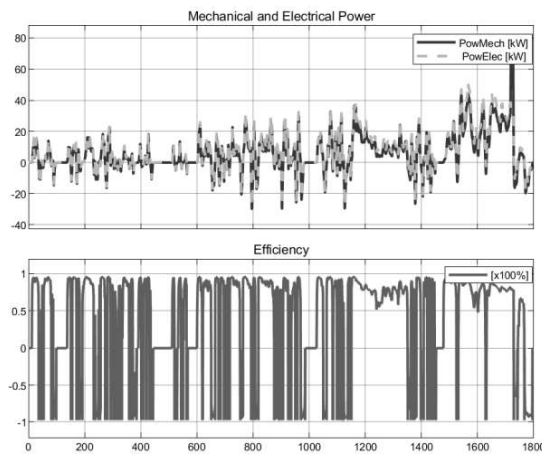


Figure 34. WLTP cycle with Power and Efficiency

4. CONCLUSION

From a mechanical and automotive engineering perspective, the study presents a dynamic analysis model for Battery Electric Vehicles (BEVs), integrating mathematical methods to assess both mechanical and electrical subsystems. Validation was performed via Matlab/Simulink simulations under NEDC and WLTP cycles. The study highlights the importance of system modeling in BEV design, detailing key drivetrain and powertrain elements such as batteries, electric motors, and thermal management. To improve simulation flexibility, the author proposes incorporating various motor types (e.g. BLDC, PMSM), battery technologies, and drive configurations. Enhancing the cooling system and testing under diverse environmental conditions are recommended for more realistic performance analysis. Expanding model validation across multiple vehicle types will allow accurate parameter tuning, enabling scalable simulations by adjusting inputs-thus increasing the model's adaptability and reliability for broader BEV applications.

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