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Simulation of a Battery Electric Vehicle Model for Longitudinal Power Train Analysis

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ABSTRACT :

Due to their shown ability to decrease the use of transportation fuels derived from petroleum and other sources with significant CO2 emissions, electric vehicles (EVs) are expected to be a part of the alternative energy environment in the future. The BEV model is built in an easily understood modular manner and is capable of operating at speeds faster than in real time. It may be used as a starting point model for drive cycle simulation to calculate the electrical efficiency and other vehicle-specific data. This study included a discussion of the BEV system's components as well as the simulation of a BEV model using the MATLAB-Simulink platform. Examination of the operation of the motor torque command, G-force, battery power, battery current, battery state of charge, and vehicle speed have been done. The powertrain model includes key elements such as the battery pack, electric motor, power electronics, drivetrain, and associated control systems. The Simscape environment enables the integration of physical parameters and realistic component interactions, providing a high-fidelity simulation platform. The battery model includes electrochemical processes, which allow for precise prediction of state-of-charge, voltage, and temperature dynamics throughout various driving situations. To accurately simulate the performance of the BEV, the electric motor and power electronics models are made to capture the minute details of torque delivery, efficiency losses, and control schemes.

Keywords: Battery Electric vehicle, MATLAB-Simulink, Simulation, Electrical Efficiency

INTRODUCTION :

Energy conservation is one of the biggest issues the environment is now facing. The importance of transportation in preserving energy in the future is stressed. This implies an understanding of the substantial influence that transport networks have on environmental and energy-related issues. Electric vehicles (EVs) are portrayed as a product of technological advancements that make life safer and easier. This emphasizes how important innovation is in solving environmental problems. [1]The emphasis on environmentally friendly and sustainable transportation options throughout the world is growing, which has accelerated the development of battery electric vehicles (BEVs). As a key enabler of the transition to electric mobility, BEVs offer the possibility of zero-emission transportation, less dependency on fossil fuels, and a path toward a more sustainable future. The rapid evolution of battery electric vehicles (BEVs) has driven significant advancements in automotive engineering, particularly in developing powertrain systems. As the automotive industry transitions towards electrification to mitigate environmental concerns and reduce dependency on fossil fuels, there is an increasing demand for sophisticated simulation tools capable of accurately modeling BEV powertrains. Among various aspects of powertrain analysis, longitudinal dynamics play a crucial role in understanding the vehicle's performance, energy consumption, and overall drivability [2]. The longitudinal dynamics of a powertrain encompass a range of critical factors, including acceleration, deceleration, torque delivery, energy management, and thermal regulation. Understanding and accurately modeling these dynamics are essential for optimizing the performance, efficiency, and overall drivability of BEVs.It takes a thorough grasp of the intricate relationships between several components, including the electric motor, power electronics, and energy storage system, to achieve the best performance, efficiency, and reliability in BEVs. In this context, modeling and simulation are essential tools that help researchers and engineers study, optimize, and forecast the behavior of BEV systems. This paper focuses on the application of MATLAB Simulink as a robust and versatile simulation environment for the modeling and simulation of BEVs.The creation of dynamic models that accurately reflect the complex dynamics of electric cars is made possible by the extensive platform provided by MATLAB Simulink.[3] This allows for the investigation of system architecture, control schemes, and overall performance attributes. This study covers the matching equation for verification, the essential electrical system components, and the modeling of the BEV. It examines all simulation results as well. The components of a battery-electric vehicle (BEV) include the driving cycle, driver model, gearbox, electric motor, battery charge controller, and longitudinal vehicle dynamic model.

METHODOLOGY :

The battery electric car components were designed using MATLAB-Simulink, which was also utilized to integrate the entire system. Additionally, MATLAB-Simulink was utilized to model the battery-electric vehicle. [4]The technical computing language MATLAB combines computation, programming, and visualization all inside one environment. It is now utilized in several fields and has been enhanced to address scientific and technical challenges. MATLAB's broad and powerful visual toolbox provides a simple and comfortable working environment.

BATTERY ELECTRIC VEHICLE COMPONENTS:

Model of Electric Motor:

It plays a crucial part in BEV. Based on a DC motor, the ensuing motor features have been created.

1. Control of Motor Speed: The motor's speed can be determined using a variety of speed techniques, voltage instructions, and procedures. It enters the motor controller as an input.

2. Braking with regeneration: The regenerative braking system uses the movement of the vehicle to produce electrical energy that recharges the battery.

$$W_c = \frac{1}{n_c}\left(\frac{mv^2}{2} + mgh\right)$$

where m is the total mass of the vehicle, v is the vehicle speed, h is the maximum height difference of the BEV and n_c is the power source's energy efficiency.

Drive Cycle

The vehicle operating schedule clarifies language related to speed and gear selection as a function of time throughout the simulation. In the US, automobiles are subjected to emission testing using the Federal Test Procedure (FTP-75) drive cycle, a standardized testing process. The FTP-75 drive cycle comprises a variety of driving modes, including idling, highway driving, and driving in urban areas, to replicate realistic driving situations.

Driver Model

For the PI controller to provide the appropriate throttle and brake commands, the driver model considers both the anticipated speed and the actual real speed. This model may be used to mimic the driver and the car. A feedback control loop is used for the speed to ensure that the vehicle is tracking the precise reference speed. The torque that the electric motor produces in response to the throttle order from the driver model is utilized as input by the gearbox model.[5]

Longitudinal Vehicle Dynamic Model

The interaction between the vehicle, tires, road, and driving system may be represented using the longitudinal vehicle dynamic model concept. The wheel circumferential speed, longitudinal wheel slip, and vehicle center of gravity speed are the three factors that determine the current condition of an electric car's motion dynamics model. To control the movement behavior of a vehicle, one must grasp all of the forces at play in its path.

Battery Model

Electric car batteries are getting better and making cars go farther on a single charge. They're also charging faster, making electric vehicles more convenient and efficient for everyone.

$$p_b = v_b * i$$

Where p_b is the Battery power in kW, v_b is Battery voltage and i is the current

Electric vehicles (EVs) are becoming increasingly electrically efficient, meaning they can cover more distances using the same amount of energy. This efficiency improvement contributes to longer driving ranges and a more sustainable and cost-effective transportation option.

$$n_e = \frac{p_b}{d}$$

Where n_e is the Electrical Efficiency, p_b is the Battery power, and d is the distance travelled by the vehicle

Motor and Vehicle Speed

The speed of an electric vehicle's motor is influenced by a combination of factors, including the gear ratio and tire radius. The right gear ratio and tire size can optimize performance, balancing acceleration and top speed, ensuring an efficient and responsive driving experience.

$$v_m = \frac{v * g}{(r_{t/100}) * 2 * pi}$$

Where Vm is the motor speed, v is the vehicle speed, g is gear ratio and r_t is the tire radius

From the above equation the speed of the vehicle can be written as

$$v = \frac{v_m * (r_{t/100}) * 2 * pi}{g}$$

The distance a vehicle can travel on a single charge is closely tied to factors like gear ratio and tire radius. Finding the right balance in these elements can significantly impact the overall energy efficiency and range of an electric vehicle, offering users a practical and reliable driving experience. The distance travelled by the vehicle

$$d = \frac{v * t}{3600}$$

From the equation the distance traveled by the vehicle is

$$d = \frac{v_m * (r_{t/100}) * 2 * pi}{g * 3600} * t$$

Where d is the Distance travelled by the vehicle, Vm is the motor speed, g is the gear ratio, r_t is the tire radius and t is the drive cycle time.

Motor torque command

Torque command in an Electric Vehicle (EV) battery system refers to the control signal that regulates the amount of torque delivered by the electric motor. It plays a crucial role in optimizing performance, efficiency, and overall driving experience by managing the power output from the battery to meet the vehicle's dynamic demands while ensuring smooth acceleration and deceleration.

Low passfilter(LF) $=1/(\frac{1}{(2*\pi*20)} * s + 1)$

$$\tau = v_{m-} v_{ref}(LF)*(k_p + (k_i)/s)$$

SIMULATION OF BATTERY ELECTRIC VEHICLE:

The gearbox model, the electric motor model, the battery charge controller model, the driving cycle and driver model, and the longitudinal vehicle dynamics model make up the five components of the simulation model, as shown in Fig. 1.[4]

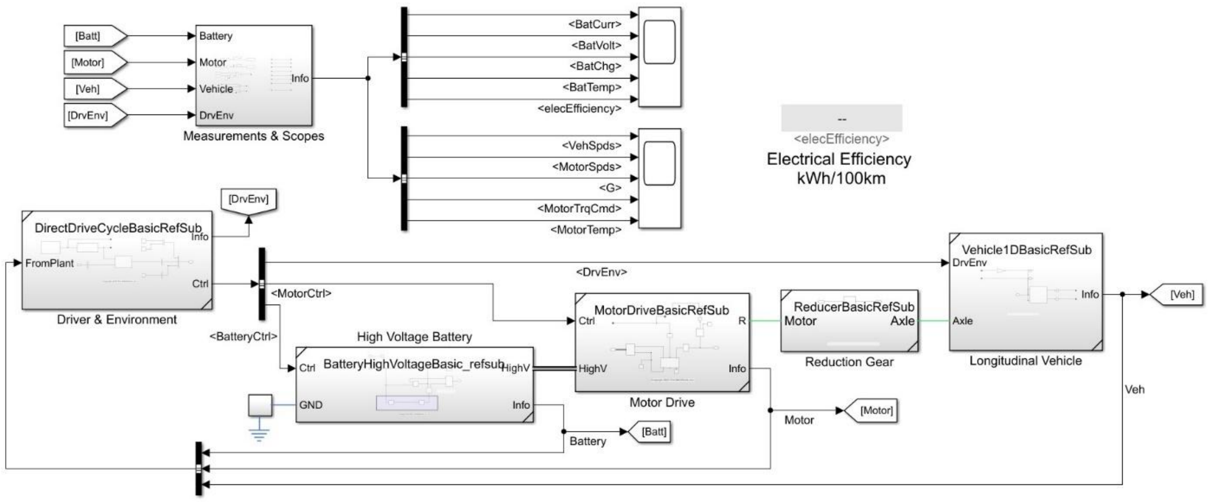

FIG 1: BATTERY ELECTRIC VEHICLE SIMULATION

RESULTS AND DISCUSSION:

The BEV simulation model was developed using mathematical formulas that are applied by each subsystem block, as shown in Fig. 1. Additionally, the battery voltage, battery current, efficiency of electricity, and battery state of charge are displayed in Figs. 2, 3, 5, and 6. It appeared from all the figures that the simulation was running well. The voltage and current of the battery are shown in Figs. 2 and 3. The graphic shows the battery current curve as taking the shape of the motor current and the necessary torque curves. We may observe a rise in battery current as a result of the greater torque needed. When the voltage and current have the same polarity, the motor can run in the normal motoring mode. However, in the case of the motor operating in the regenerative-braking mode (a generator), the power moves in the opposite direction and the current becomes negative.

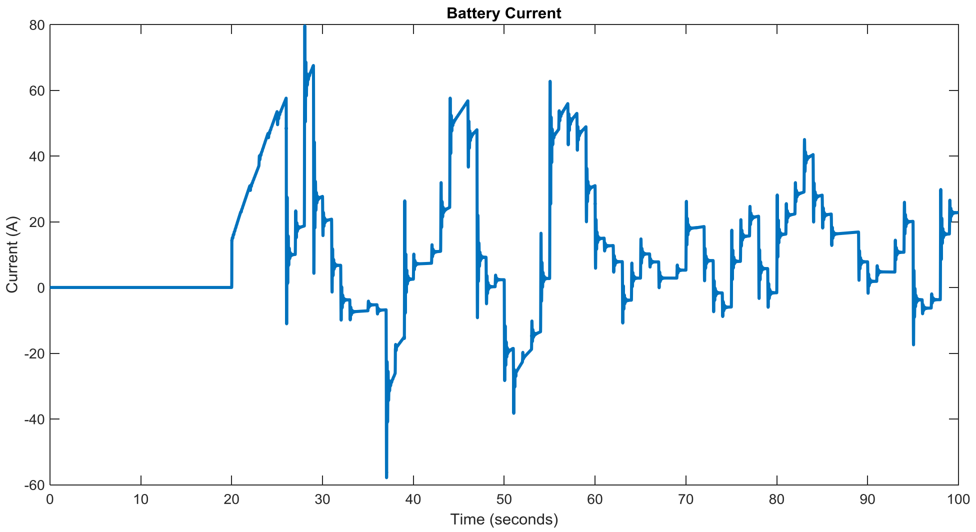

FIG 2 : BATTERY CURRENT

The FTP-75 drive cycle is a standardised test used to assess the emissions and fuel efficiency of vehicles. It has a number of driving modes, such as rest intervals, cruising, deceleration, and idling. In an electric car, these factors affect how much current is taken from the battery. The electric motor takes more electricity to boost speed during acceleration than it does at idle times. The current stays mostly constant when travelling in a steady condition. During deceleration, regenerative braking devices are frequently employed to convert kinetic energy back into electrical energy. To optimise the performance of electric vehicles, it is imperative to regulate these oscillations efficiently.

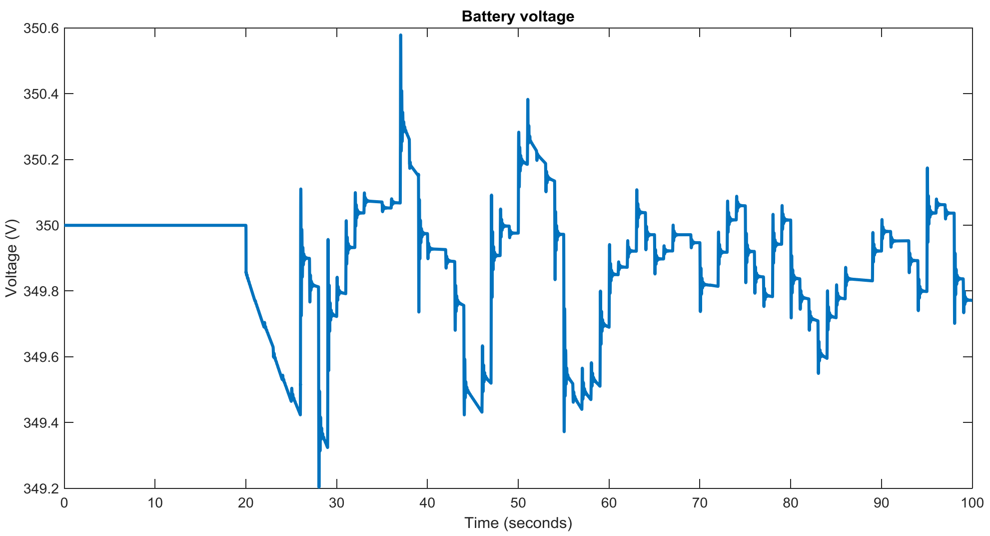

FIG 3: BATTERY VOLATGE

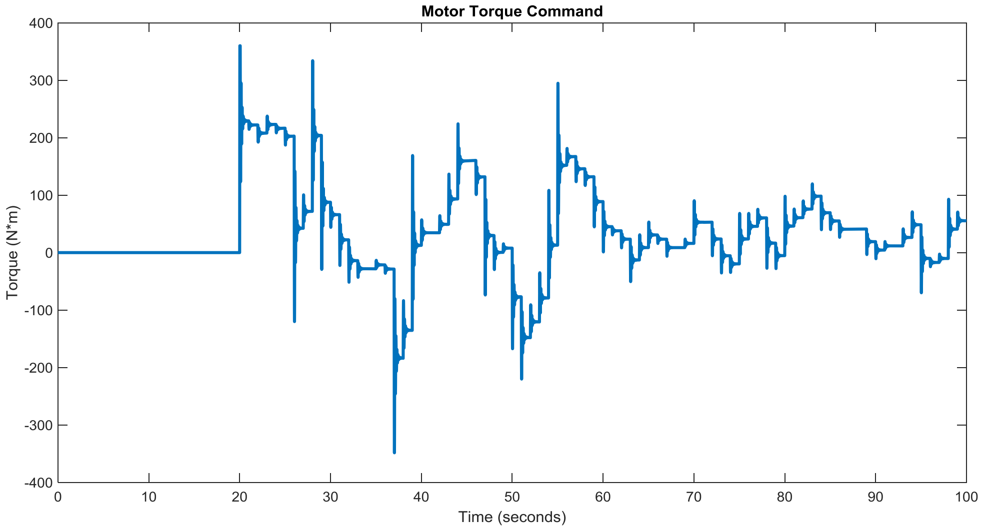

FIG 4: MOTOR TORQUE COMMAND

For a given current, a motor that has a higher torque constant generates greater torque; conversely, a motor with a lower torque constant produces less torque. The torque production may be controlled by varying the current sent to the motor. For example, if other variables like motor speed and temperature stay constant, then increasing the current flowing through the motor windings will result in a proportionate increase in torque production.

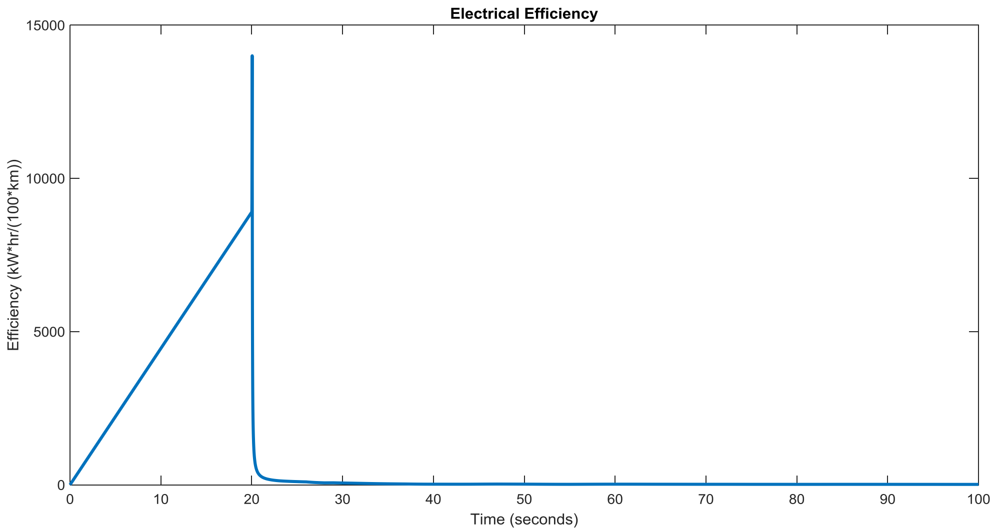

FIG 5:ELECTRICAL EFFICIENCY

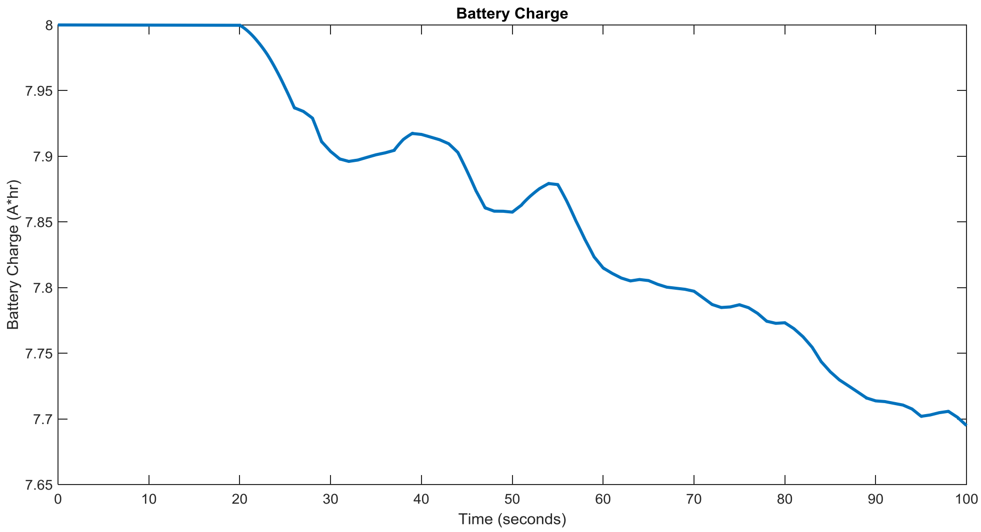

FIG 6: BATTERY CHARGE

A vehicle's driving cycle is greatly influenced by the battery charge level, especially in electric cars (EVs). Because of the increased energy provided by the battery's initial charge, the vehicle can go farther between charges. The propulsion system of the vehicle uses electrical energy from the battery, which is affected by several elements such as road conditions, accessories, speed, and acceleration. Regenerative braking systems replenish the battery and increase overall energy efficiency by capturing kinetic energy during braking or deceleration. The battery's charge level drops during the drive cycle, necessitating recharging on occasion to keep it operating at peak efficiency. For optimal battery utilisation and a dependable driving experience, effective battery management systems are essential.

CONCLUSION:

This study looks at the energy flow, performance, and efficiency of BEVs and their components using simulation. Good outcomes for the voltage of the battery, current, power, and state of charge were obtained using MATLAB-Simulink. There are still plenty of chances to develop a better BEV model, which will act as the basis for future research. To minimize energy usage and identify the optimal voltage, current, power, battery state of charge, and correct component size, automobile designers rely heavily on modeling and simulation.

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