International Journal of Research in Science Advanced Technology and Management Studies
ISSN NO: 2249-3034

# Advanced Powertrain and Battery Pack Modeling for EVs

Guided by- Prof. Dr.HENRY Vaishnavi Nare ,Shubham Gorade, Aniket Kirdak .
(Under graduate)

Department of Electrical Engineering, Maharashtra Institute of Technology(MIT),Beed ByPass ,Aurangabad

***Abstract*— This research presents a comprehensive modeling and simulation approach for electric vehicle (EV) powertrain and battery pack configuration, encompassing battery pack architectures, powertrain dynamics, battery behavior, and a unified simulation platform. Powertrain Modeling, A detailed model of the electric motor, power electronics, and gearbox is developed to capture their dynamic behavior under various operating conditions. This includes torque-speed characteristics, efficient maps, and transient response. The paper explores different battery pack architectures, including series, parallel, and hybrid configurations. A detailed analysis is conducted to determine the impact of pack configuration on energy density, power delivery, thermal management, and overall vehicle performance.**

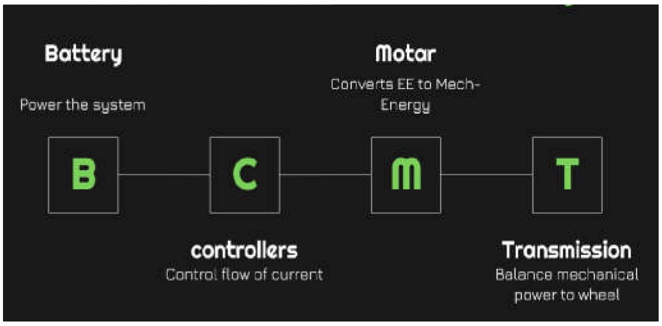
***Keywords— Electrical Vehicle (EV), MATLAB/ Simulink, powertrain and battery pack configuration***

## I. INTRODUCTION

T Unlike traditional internal combustion engine (ICE) vehicles, EVs rely on electric motors and high-capacity batteries to generate and store energy, making the design and optimization of the EV powertrain an even more critical endeavor. The powertrain simulation in EVs goes beyond replicating traditional mechanical components found in ICE vehicles. It encompasses intricate electrical and electronic systems that govern energy flow, regenerative braking, thermal management, and the overall efficiency of the electric drivetrain. This simulation enables a comprehensive understanding of how different powertrain components work together under various conditions, leading to more efficient and higher-performing EVs.

The arrangement of individual battery cells that make up the pack. The configuration of the battery pack can have a significant impact on the overall performance and range of the vehicle. This paper delves into the intricate domain of EV modeling, with a specific focus on the simulation of battery pack configurations. By employing advanced modeling techniques and simulation tools, researchers and engineers can explore various aspects of EV battery design, including arrangement, thermal management, and overall performance

## II. Block diagram of Electric vehicle




Electric Motor: Converts electrical energy into mechanical power. Battery Pack: Stores and supplies electrical energy. Inverter/Power Electronics: Controls the motor by converting DC to AC. Transmission/Gear: Adjusts power delivery to the wheels (not always present). Differential: Distributes power to the wheels. Drive Shafts/Axles: Transmit power to the wheels. Wheels: Responsible for vehicle movement. Regenerative Braking: Recaptures energy during braking. Controller/ECU: Manages powertrain components. Thermal Management: Regulates temperature for efficiency. HV Distribution: Distributes high-voltage power. LV Electronics: Controls auxiliary systems.

## III. Simulation technique in EV modelling-

Simulation techniques play a crucial role in modeling electric vehicles (EVs) to assess their performance, efficiency, and various other aspects. These techniques help researchers, engineers, and manufacturers to design, analyze, and optimize EV systems without the need for physical prototypes, which can be costly and time-consuming. Here are some common simulation techniques used in EV modeling:

- Battery Modeling: Battery models or physics-based models simulate the behavior of batteries in EVs, considering factors like state of charge (SoC), state of health (SOH), and temperature effects.

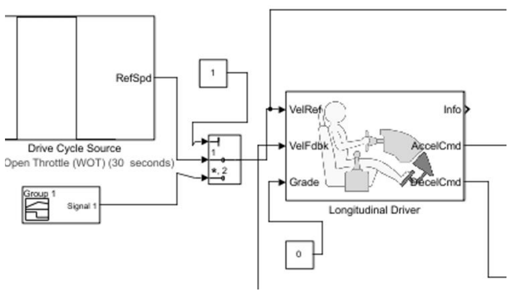
ISSN NO: 2249-3034

Powertrain Modeling: These models simulate the powertrain components such as the motor, inverter, and gearbox, considering their physical properties and interactions. Drive Cycle Simulation: EVs are often tested under various drive cycles (e.g., NEDC, WLTP, or custom cycles) to estimate energy consumption and range. These simulations use real-world data to mimic driving conditions. Power Electronics Simulation: Simulating the power electronics components like the inverter and converters helps optimize control strategies for energy efficiency and motor performance. These simulation techniques, often performed using specialized software tools like MATLAB/Simulink, ANSYS, or specialized EV simulation platforms

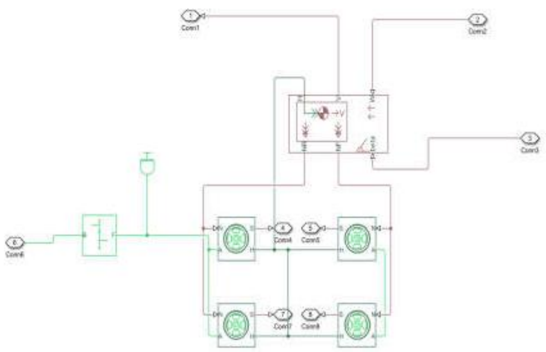
# IV. Powertrain

A. Driver Block: -

The power essential to drive the vehicle should be known before describing the power management from the vehicle dynamic. This block is responsible for driving the whole model. The controller oversees generating the motor's driving signals. It stimulates the driver's accelerating and braking actions to match the intended driving cycle. This diagram contains a longitudinal block, which gives the command of acceleration and braking to further block depending upon reference rate input to longitudinal block. In this system we generate the customized signal by the signal builder block.



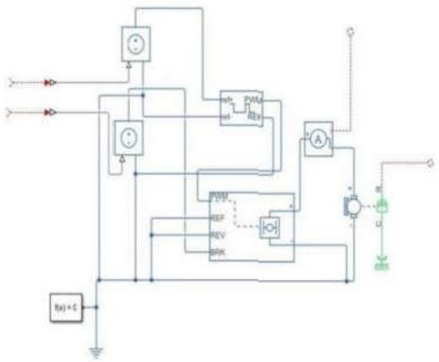

B. Subsystem of the Electric vehicle:



This is the subsystem of the vehicle which contains the Tyres, vehicle body block, the gearbox and the inertia block.

C. Circuit for motor operation

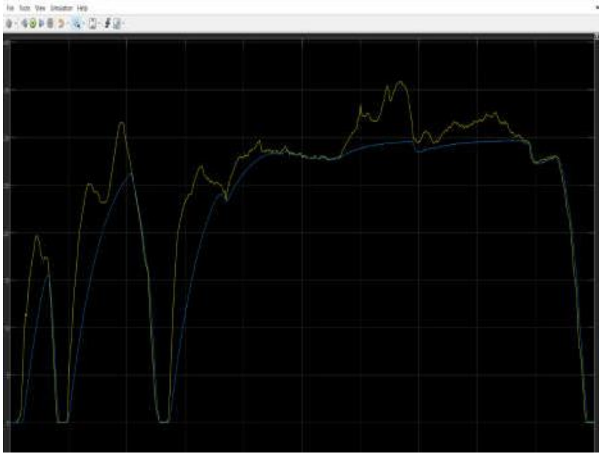
This system contains the PWM block which is responsible for the motoring operation either in forward or reversed direction. The signal from longitudinal block is physical signal so to convert in electrical we are using the current control block.



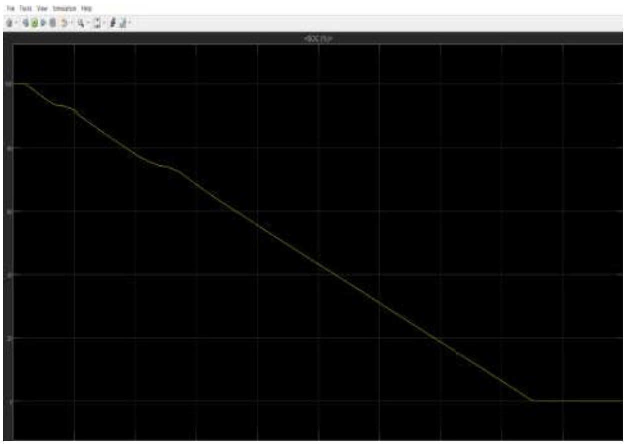

# V. Electric Motor Modeling Powertrain: -

Mathematical Modeling: Begin by developing mathematical models for each major component of the powertrain. These models should describe the physical behavior and characteristics of each component. Key parameters include:
Electric Motor: Model the motor's torque-speed characteristics and efficiency maps. Various motor types (e.g., induction, permanent magnet) may require different models.
Battery Pack: Develop a battery model that captures its voltage, state of charge (SoC), state of health (SoH), and thermal behavior. The model should account for factors like internal resistance, capacity degradation, and temperature effects.
Inverter: Create a model that simulates the inverter's control strategy, including its switching behavior and efficiency.
Transmission (if applicable): If your EV has a multi-speed transmission, model its gear ratios and efficiency to account for power transfer.
Transmission Modeling (if applicable):
Gear Ratios: Model the transmission's gear ratios and shifting behavior.
Efficiency: Include transmission efficiency to account for power losses during gear changes.
Validation and Testing:
Validate the powertrain model by comparing simulation results with real-world data from physical testing and actual vehicle performance.

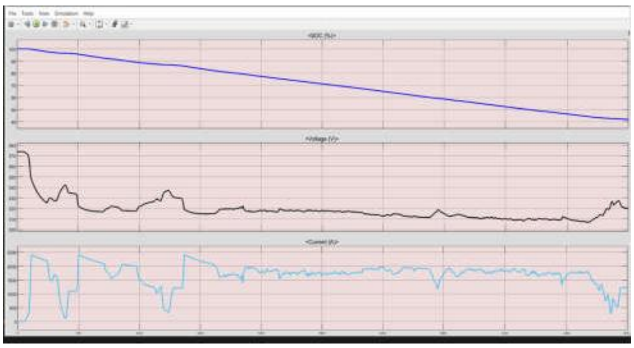
## VI. Result and Analysis-



The graph of the reference speed and actual speed of the vehicle



This is the graph of SOC level in the system.

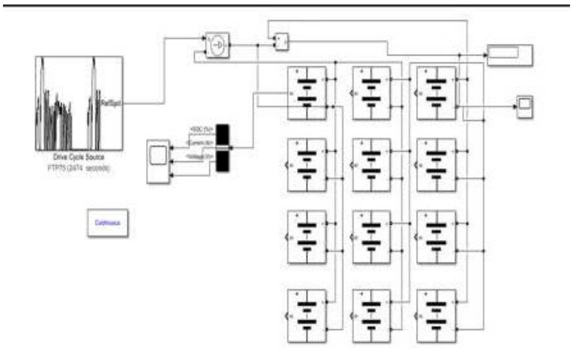


The graph of current, voltage and the SOC (state of charge) in the system, and their comparison.

## VII. Battery Block

The battery pack in an electric vehicle (EV) serves as the energy storage and supply system. Comprised of multiple lithium-ion battery cells, it holds electrical energy. A Battery Management System (BMS) oversees individual cell health, voltage, and state of charge, ensuring safety and optimal performance. The cells are arranged in series and parallel configurations to achieve the desired voltage and capacity for the EV's requirements When the driver accelerates, the battery pack delivers energy to the electric motor via power electronics, which converts the stored direct current (DC) energy into alternating current (AC) for the motor. The motor then converts electrical energy into mechanical power, propelling the vehicle. Regenerative braking allows the motor to act as a generator during deceleration, recapturing energy for recharging. The state of charge is continually monitored, and the battery can be replenished through various charging methods, ensuring a vital role in the EV's operation,

## VIII. Battery pack configuration simulation -



This is the overall simulation of battery pack in Electric vehicle. Containing a driver cycle as a source, batteries. This simulation shows you the current voltage level of the battery. By this you can calculate the efficiency of the battery, the depth of discharge (DOD), and the state of health (SOH) of the battery.

## IX. Mathematical Modelling of Battery Pack; -

Travel Factor= total travel / travel in speed
Battery Pack = Power * travel factor/ (motor + pack efficiency)
Efficiency (%): Coulombic Efficiency = (Discharge Capacity / Charge Capacity) × 100
Energy (kWh) = Voltage (V) × Capacity (Ah) × Number of Cells × Efficiency

Depth of Discharge (DoD): DoD (%) = (Initial Capacity - Remaining Capacity) / Initial Capacity
State of Health (SOH): SOH (%) = (Initial Capacity - Current Capacity) / Initial Capacity × 100

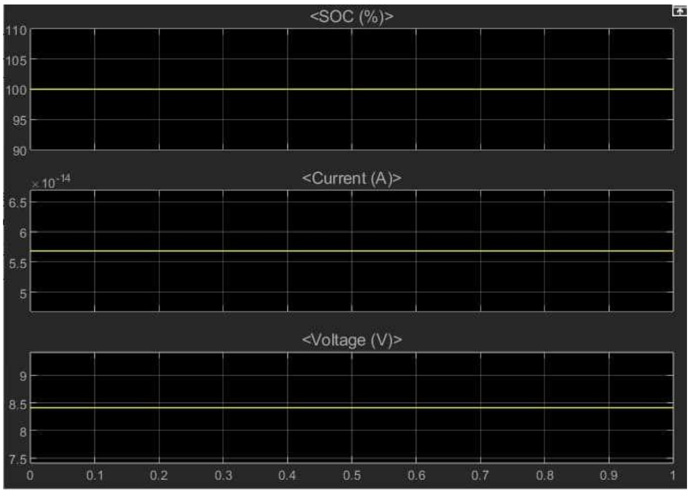
# X. Series vs Parallel Battery Pack Configurations in EV modelling

In short, series battery pack configurations in electric vehicles (EVs) offer higher voltage and efficiency at high speeds but lack flexibility and can be less redundant in case of cell failure. In contrast, parallel battery pack configurations provide greater capacity, scalability, and redundancy but may require higher currents and more complex control systems. The choice depends on the specific EV requirements, with some vehicles opting for hybrid configurations to balance voltage, capacity, and flexibility.

# XI. Thermal management strategies in Battery Pack Configuration; -

Coolant Circulation: An active thermal management system uses a liquid coolant (usually a mixture of water and glycol) to absorb and dissipate heat generated during battery operation. This coolant circulates through channels or tubes within the battery pack.
Thermal Plates: Thin metal plates or heat spreaders are often integrated into the battery pack design to distribute heat more evenly across the cells.
Fins: Fins attached to the cooling plates increase the surface area for heat dissipation and help regulate temperature.
Thermal Barriers: Insulating materials can be used to create barriers between the battery pack and external elements to maintain a consistent temperature.
Encapsulation: Some battery packs are encapsulated in thermally insulating materials to protect them from extreme temperature variations.
Effective thermal management strategies not only ensure the safety and performance of EV battery packs but also contribute to the overall efficiency and durability of the vehicle. Manufacturers continually refine and optimize these strategies to enhance the thermal performance of their EVs.

# XII. RESULT and ANALYSIS-




# XIII. Conclusion -

This research has shed light on the intricate complexities of EV powertrain design and optimization, emphasizing the paramount importance of factors such as electric motor efficiency, battery technology, and energy management systems. Analysis of the current-voltage-speed relationship in Electric Vehicles (EVs) is a fundamental aspect of understanding and optimizing their performance characteristics. This study has highlighted the intricate interplay between these parameters, showcasing how current and voltage affect the speed and efficiency of EV.

# XIV. REFERENCES

1]. A. Kavi, "A review paper electrical vehicle powertrain system components and the challenges involved in their large-scale introduction," in International Research Journal of Engineering and Technology, vol. 9, March 2022.
2]. S. H. Guanhao Du, Wenping Cao, "Design and assessment of an electric vehicle powertrain model based on real-world driving and charging cycles," vol. 68, 2019.
3]. D. K. Vedant Tomar, A Chitra, "Design of powertrain model for an electric vehicle using Matlab/Simulink," 2021.