Design and Simulation of Electric Vehicle Powertrain Kinematics and Components Using MATLAB/Simulink

Bapu Kokare[1], Sanjay Deokar[2], Mangesh Kale[3]
[1]Research Scholer, Department of technology, Savitribai Phule Pune University, Pune, India
[2]Principal, Sharad Pawar College of engineering, Someshwarnagar, SPPU, India.
[3]Principal engineer, Eaton Ltd. Pune, India
Emails: *bapu.kokare1990@gmail.com[1], s_deokar2@rediffmail.com[2], mangeshkale@eaton.com[3]*

Abstract
The introduction of electric power trains is a significant factor that has made it possible to come up with power trains with unique characteristics needed for EVs. In this paper, the simulation of electric vehicle powertrain and Modeling and simulation of electric vehicle powertrain with MATLAB/Simulink has been made in depth for the design of Electric vehicle powertrain. This include detail modeling of the elements of the powertrain including the electric motor, the transmission system, and the battery pack together with the vehicle dynamics. In this case kinematic analysis of mechanical and electrical subsystem is done in order to determine compatibility for torque and speed of different cycles of drive. This allows for characterization of the component's performance during dynamic situations and the assessment of the entire system response, power consumption and drivetrain dynamic characteristics. The outcomes confirm MATLAB/Simulink to be a viable tool in the study of Electric powertrains as a vehicle concept and an effective medium on pre Relative Layout stage and compressed electrical automobile advancement.

Keywords: *electric power trains, electric vehicles, Modeling and simulation, MATLAB/Simulink, kinematic analysis.*

1. Introduction

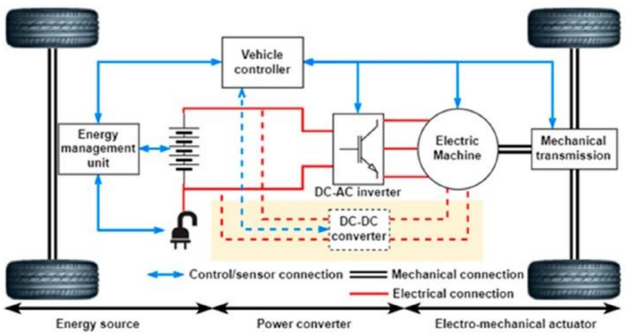


Figure 1 Overview of Electric Vehicles (EVS) and The Significance of Powertrain Design

The usage of electric vehicles is gradually becoming popular as the ICE vehicles, in a bid to mitigate the effects of pollution, long reliance on fossil energy sources and noise pollution across the global market. Contrary to ICEs, EVs contain electrical motors that are driven by the on-board energy storage system that is the batteries most often lithium-ion. [1] The electric powertrain is an important aspect of any electric vehicle, and involves elements that enables appended to engender mechanical power from electrical energy. The electric equivalent of engine is called the electric powertrain and for its proper functioning it has a traction motor, inverter, battery system, transmission and control unit for the smooth acceleration and regenerative braking system, torque control and energy conversion. [2] Selecting and optimizing the design of a powertrain is crucial to achieving the required range and performance in electric vehicles as well as fully aligning with requirements of legislation and the buyer. Thus, efficient and behind the powertrain visions, adequate electric mobility is still one of the most prominent and significant aspects in EV rivalry (Figure 1). [3]

1.1. Motivation for Simulation-Based Design Using MATLAB/Simulink

The development of an electric vehicle is not simple and yet is multi-disciplinary task which demands the proper modeling of electrical, mechanical, and control elements. The current most common methods of physical prototyping are more time-consuming, costly, and restrictive especially at the first stages of designing. It is here where simulation tools turn out to be extremely effective. First of all MATLAB/Simulink is an effective tool for modelling, simulation and analysis of complex systems and processes, the main element of which is the Mathematical Workplace of MathWorks company. It let engineers create schematics of certain components and test the system or components efficiency in different conditions and parameters, as well. [1] The reason for the applicability of MATLAB/Simulink in EV powertrain design is all the more due to its well-endowed resources present in MATLAB/Simulink for built-in toolbox for electric drives, modeling of battery, dynamics of the vehicle, and control systems. The advancements achieved by means of this platform are faster development cycles, decreased costs of prototyping, better means for structure improvement and higher reliability and reproducibility of the simulations. Also, the integration of the real-time HIL testing and the controllers' development makes MATLAB /Simulink an ideal tool in research and development studies.[4]

1.2. Problem Statement

With the global focus towards sustainability in the transportation system, the use of ICE vehicles has been replaced by EVs in the recent past. In the light of the current advances in EVs, one of the major issues relates to the advancements in the powertrain components that may be used to guarantee success in performance, energy efficiency, and reliability. The design and integration of an electric powertrain also involve understanding several factors which include mechanical drive, kinematic, electromagnetic, and other dynamic characteristics of various components like motor, battery, transmission, vehicle body and other parts. However, the physical prototyping of such systems takes considerable amounts of time and is very expensive, especially in the initial designs. Furthermore, most analyzed specialized models do not include a modular and simulation-based approach that would enable testing and fine-tuning of various layouts depending on the powertrain under different driving profiles. Consequently, there is much demand for a simulation-related approach that will help in the design and modeling of the electric vehicle powertrain as well as the evaluation of its performance. MATLAB/Simulink has the capability to meet this requirement, yet, more research and development are needed to incorporate the software's capacity for simulating the intricate kinematic processes of EV powertrains. That is why this work is aimed at creating a detailed and modular simulation model of an EV powertrain at the MATLAB / Simulink platform, which will contribute to making correct decisions in the powertrain and developing the process of creating electric vehicles.

1.3. Objectives and Scope of the Study

The first goal of this work is to model and simulate the electric powertrain system for electric vehicle which depends on various components and their dynamics in Words MATLAB/Simulink environment. The modeling and simulation of the necessary powertrain components like motor, powertrain system, and battery pack as well as vehicle body are the key objectives of the study. During the kinematic modeling and dynamic modelling, it is a goal of this research to determine how these parts impact the total vehicle performance depending on the given drive cycle. This work does not include further control measures as torque vectoring or thermal control, although they should be addressed in subsequent works, and the study is restricted to longitudinal vehicle dynamics. Its results will then be used to measure the effectiveness of design-related decisions on performance indicators such as energy, acceleration response, and state of charge (SOC). In conclusion, this work was designed to be a basis for future investigation of the EV powertrain and associated controller advancement as well as an example of how MATLAB/Simulink can be used in the initial stages of the configuration of an electric vehicle.

1.4. Novelty of Work

This research introduces a simulation-driven methodology for designing electric vehicle (EV) powertrains that combines conventional kinematic modeling with intelligent control strategies within MATLAB/Simulink. The novelty lies in its modular architecture that supports the future integration of AI-based optimization algorithms and machine learning

International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2025.0257
e ISSN: 2584-2854
Volume: 03
Issue: 05 May 2025
Page No: 1587 - 1598

for parameter tuning, predictive performance analysis, and adaptive control. Unlike traditional simulation models, this framework is structured to accommodate intelligent components, such as data-driven motor control and energy management systems. This positions the study at the intersection of EV systems engineering and artificial intelligence, offering a flexible foundation for next-generation smart vehicle applications.

2. Literature Survey

Numerical modelling and simulation of electric vehicle power-train is an important area of research in the current years because it is at the frontier of power-train technology and its necessity is widely acknowledged because of the rising demand for efficient and eco-friendly transportation systems. There are several methods, which have been used and created in order to apply simulation on the design and further analysis of the EV systems. These include MATLAB/Simulink, AVL CRUISE, GT-SUITE, CarSim, PSIM and ANSYS Twin Builder which come with different levels of accuracy, flexibility, and suitability for different model uses.[5] Although AVL CRUISE and GT-SUITE can be most applied for industry virtual simulations and their integration with actual dynamometer cells, MATLAB/Simulink is widely used in academic researches as it offers more open modelling environment, Simscape libraries and may be easily connected to the control algorithms and real time testing modules. [6] These tools allow designers to perform a drive cycle, energy consumption assessment, stresses on the individual components, a controller in the loop and finally a hardware in the loop simulations without having to use actual vehicles which time and money consuming to build. [7] A few significant discrepancies show the difference between the ICE power plants and electric power plants. ICE systems include engine, clutch, multi-speed transmission, exhaust, and fuel system to name but a few, and this implies that they bear a numerous number of components that cause energy loss through friction and heat dissipation.[8] On the other hand, powertrains of EV have far fewer components such as an electric motor, power electronic controller, battery pack and, simple or fixed-ratio transmission system. EVs offer instantaneous torque, regenerative braking capabilities, higher energy conversion efficiencies, and lower maintenance costs.[9] But there is still issue regarding energy storage management, first and foremost thermal issues and second the complexity of the drivetrain control. These differences make it essential to adopt a new design and simulation methodology of Evs one that can accommodate nonlinear dynamics, transient response as well as interaction between systems. [10] Several research has used MATLAB/Simulink for the formulation and validation of powertrain models of electric vehicles. For instance, Ehsani et al. utilized Simulink to model brushless DC motor (BLDC) as well as permanent magnet synchronous motor (PMSM) for EV propulsion system. Other works have synchronized the energy storage systems with drive cycles such as the UDDS and WLTP for range, efficiency, and battery wear estimation. [11] Subsequent studies have been made on the simulation of regenerative braking, traction control and two motor control by the MATLAB control system and the optimization toolbox. Moreover, some authors have used MATLAB/Simulink in Hardware in the Loop (HIL) environment for the analysis of real-time controllers. Although, significant studies have been conducted towards the improvement of EV modeling, the future of even a nearly complete EV model construction has not had considerable work done in terms of a modularity and reusability FEA with focus on kinematic behavior and integration aptitude of the system. [12] This study aims at filling this gap by developing a complete modeling and simulation platform to serve power train systems of the EV using MATLAB/Simulink. The MATLAB/Simulink simulations have been effectively used for the modelling of the electrical and mechanical aspects of the EV power train. For example, in, Ehsani et al explained how Simulink/MATLAB was used in analysis of vehicle propulsion system that incorporated PMSM and BLDC, which are crucial in electric vehicles. As it has been identified earlier, the main interests of these models were on the motor control, optimization of the efficiency and energy recuperation technologies which included the regenerative braking. [13]Other large topics of

International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2025.0257
e ISSN: 2584-2854
Volume: 03
Issue: 05 May 2025
Page No: 1587 - 1598

research have included lithium ion batteries and supercapacitors for the purpose of energy storage evaluating their efficiency and aging over different types of cycles [14]. Moreover, in the modeling of vehicle dynamics with MATLAB/Simulink, there is also the modeling of tires road side, suspension, and kinematics of electric vehicle under different driving conditions. However, there are some of the missing in the current studies that warrant further research to effectively enhance the performance of EV powertrains. For instance, research on the separation of the individual links of the vehicle, say the motor or batteries, has been quite extensive while schemes for linking the different kinematic loops of the automobile to the performance of the whole powertrains link have not been adequately explored. Whereas most existing models work with the subsystems as a black box isolating them from other subsystems researches lack an insight of how the vehicle's electromechanical system interacts at the system level [15]. Moreover, while several simulated subcomponents using the MATLAB/Simulink tool have been implemented by various researchers, relatively less emphasis has been laid on creating general-purpose, flexible, and modulated simulation models that can be shared, modified, and reused for dissimilar automobile structures. Hence, the research gap is the lack of an elaborate simulation model that not only simulates both the electrical and mechanical subsystems but also performs kinematic analysis of the total EV powertrain. [16] Current works, however, tend to study aspects of electric vehicles solely as powertrain sub-systems motor and battery systems or mechanical sub-systems transmission, suspension systems without reference to each other or control as a system with coupled components. There are no high-level reference models and no models that are pre-built and modular in a way to be rather easily adapted for use with different vehicles; this decreases the generalizations and opportunities for reuse of current work. [17] Another important issue is that the sufficient attention to the methods such as real-time simulation and HIL testing is missing. Although some works have been done up to this view point there is a lack of work in Real-time control and system level simulation for the whole powertrain system including motor controllers energy storage and power electronics. [18]Accurate real-world behavior of the powertrain may be achieved if a HIL setup combines its kinematic behavior, as well as the electrical and thermal models. Also, discussions of regenerative braking and energy management have been done with a lot of emphasis; nonetheless, more attention should be given to discussing high levels of control strategies and corresponding optimization that can change depending on the conditions of driving, load, and state of charge of battery. [19]These advanced control algorithms have to be embedded in a format that would allow simple integration within a MATLAB/Simulink that is also flexible and scalable for modeling a full scale EV powertrain system for yield optimum vehicle performance. Thus, it can be concluded that while the literature contains a significant amount of information regarding individual sub-systems responsible for electric vehicles, more research is needed in the in the sense of multi-disciplinary simulation of kinematics of entire EV power train system. [20]Addressing this gap will be the objective of this research, where a modular simulation environment using MATLAB/Simulink will be created to enhance the evaluation of potential options and decisions in designing and optimizing EVs.

3. System Architecture and Key Components

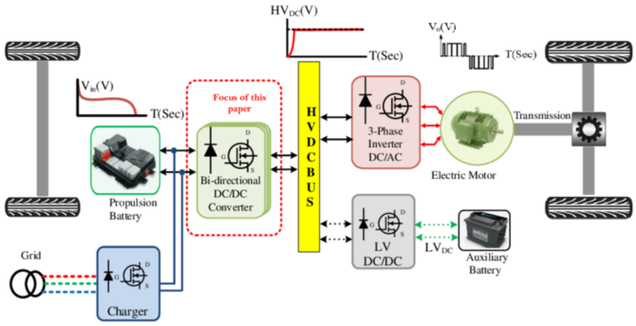


Figure 2 Simplified Block Diagram of Battery EV Powertrain [1]

The detailed block diagram of the electric vehicle (EV) powertrain system basically involves these components outlined below that have a close relationship with each other in performing their respective functions in the vehicle (Figure 2). There are five major subsystems of EV powertrain; electric motor, power electronics which is the inverter and controller, energy storage system which is a lithium-ion battery pack, the transmission system and lastly the wheels. The energy storage system supplies electrical energy to the electric motor which in turn convert this kind of energy into mechanical power. [21]The power electronics relate to the control of power to the motor through the battery by regulating the speed and torque of the motor. The power transmission system or simply powertrain, normally in the form of a single speed gearbox interconnects the motor with the wheels for movement of the vehicle. The block diagram also features feedback systems of regenerative braking which allows the energy during braking to be retrieved from the battery. [22]All of these work together in a system which is controlled by the vehicle control unit or VCU which oversees functions of all the components with the aim of providing maximum efficiency in terms of energy use, performance as well as safety. Furthermore, input sensors including state-of-charge, temperature, speed, etc., enable real-time optimization of the powertrain related parameters in the vehicle. The motion transmission system of an electric vehicle (EV) is defined as the arrangement by progressive parts that connect the electric motor to the wheels through which power is transmitted, allowing movement of the vehicle. This chain of operations begins with the electric motor that is driven by energy derived from the battery. [23]The motor produces Twist, as in the force which must be used to rotate the vehicle in question, and this is referred to as torque. This torque is then transmitted through the transmission system for example single speed gearbox in most electric vehicle to control the speed and supply suitable torque required by the wheels. [24] The transmission system largely assist in transforming the high rpm and low torque of the electric motor to the right rpm and torque to drive the wheels and thereby achieve vehicle movement. In EVs, the relationship between the torque of the motor and the speed together with the supplied power from the battery puts the motor-transmission-wheels as an essential component of the vehicle performance. It is also worth noting that the kinematic chain of the electric vehicle is easier than that of the ICE vehicle due to the absence of multi-gear transmissions, thus improving efficiency and lower cost of maintenance and a smoother drive. [25,26]

3.1. EV Drive Cycle

A drive cycle refers to a series of benchmark procedures that are employed in order to model actual road usage patterns when conducting tests on a certain car. Drive cycles are conversely paramount for assessing the usage of energy, the range capacity, as well as the output of emissions of any EV under theoretical settings. Some of the global cycles employed for EVs are the NEDC, the WLTP, and the FTP-75. NEDC (New European Driving Cycle): This is the test that has been adopted by Europe in measuring the fuel consumption as well as emission levels of vehicles. This is a synchronized representation of urban and extra urban driving cycles mainly involving low and high speed simulations of an urban driving environment. The advantage of this approach is that it is simple; however, the disadvantage is that it has been deemed inadequate for the modern algorithm since it lacks realistic driving simulations specifically for electric cars. WLTP (Worldwide Harmonized Light Vehicles Test Procedure): The WLTP as a test procedure is less artificial and close to real life once compared to the NEDC. It is used globally and contains more oscillatory nature driving cycles, higher velocities, and acceleration in comparison to the NEDC. WLTP has become the standard for EV testing in the European market more closely mimicking urban, suburban and highway driving conditions. FTP-75 (Federal Test Procedure 75): The FTP-75 is a drive cycle which is used in the United States for the purpose of determining the vehicle emissions and the fuel economy. They mainly mimic urban driving cycle which contains a predominant proportion of stop-and-go traffic including a small percentage of highway driving. It is applied to measure electric vehicles' energy usage and its solution's performance within the United States markets.

3.2. System Components

Electric motors are claimed to be one of the most important systems of the EV power train converting electrical energy into mechanical energy. Some of the popular electric motor structures fitted in electric

International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2025.0257
e ISSN: 2584-2854
Volume: 03
Issue: 05 May 2025
Page No: 1587 - 1598

vehicles include the Brushless DC motor also referred to as the BLDC motor and the Permanent Magnet Synchronous Motor (PMSM). These advantages are high efficiency, maximum durability, high reliability and low maintenance due to lack of brushes that make it suitable for use in automobiles. PMSMs are currently famous for their high power density and the ability to deliver torque evenly, and they are widely applied in high-performance electric vehicles. In case of these induction motors, the torque-speed characteristics differ according to their designs. The BLDC motors operate at low speed with high torque and has an optimum torque at the maximum rotational speed. As for PMSMs, torque-slip characteristic is more linear and there is higher efficiency at a wider operating range. There are some important characteristics incorporated for choosing the best motor in accordance with the performances of the car. In most electric vehicles, the transmission system is less complex compared to that in internal combustion-engine vehicles. Most of today's typical EVs have a single gear or directly controlled just like automatic sedans, as the electric motor offers an extensive area of coverage of the density of torque. However, some of the high-performance electric vehicles come equipped with a multi-speed transmission to enhance the torque and efficiency. The nature of torque in motors together with the speed and acceleration performance of a vehicle or automobile determines the gear ratios in the multi-speed transmissions. The gear ratio, "I" is expressed as the relationship between the speed of the motor and the speed of the wheels as follows;

$$i = \frac{\omega_{Motor}}{\omega_{Wheel}}$$

Where, ω stands for the angular velocity of motor or wheels. Proper choice of the gear ratio is crucial for the motor proper functioning and thus achieving maximum utilization of available power with maximum losses. Battery pack as a power supply of vehicles is made up of a number of cells connected in series and parallel in order to achieve the appropriate voltage and energy capacity. It has been found that the cell configuration plays a significant role in the energy density, voltage as well as the capacity in the battery pack system. The State of Charge (SOC) of the battery is a critical factor based on which the usable energy for propulsion can be defined. Thus, SOC modeling allows to monitor the extent of battery degradation and its charge and discharge cycles. Battery pack energy storage capability is normally rated in kilowatt hours (kWh) of energy, which correspond to the amount of energy the pack can provide to the motor. SOC modeling together with thermal management makes the battery safe as well as ensure longevity as a result of protecting it from the effects of overcharging or deep discharge that are harmful to the battery. In an electric vehicle, the controller's purpose involves regulating the motor's speed as well as the torque for efficiency and functionality. As for speed and torque regulation, it is normally done in a closed loop system and measurements are taken regarding motor speed as well as the torque being exerted and the controller conforms to the desired or set values. The power conditioning and control of DC power from battering to AC power is also modeling that drives the motor. Since the inverter controls the output frequency and amplitude of the voltage, it determines the speed and torque of the motor. FOC or Direct Torque Control methods are modern control strategies that enable the motor to operate more smoothly and in a more efficient, and accelerate faster. Some of the ways in which the vehicle body design affects the longitudinal dynamics include acceleration or deceleration of the vehicle's axes or the manner in which the body work s during acceleration and braking forces. The main sources of resistive force that comes against the vehicle are rolling resistance and air drag. Rolling resistance associated with the interaction between tires and the surface of roads depends with the weight of car and nature of the tires. Specifically, rolling resistance is the force by which the tires of the moving vehicle resist the pushing force while aerodynamic resistance on the other hand is the drag force experienced by the moving vehicle when progressing through the air and it may depend on the form of the car, velocity and the drag coefficient. Both are important when estimating the energy requirements and the mobility radius of the vehicle. The overall resistive force is then added to the measure of the torque generated by the actual motor to estimation of acceleration, maximum velocity, and

International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2025.0257
e ISSN: 2584-2854
Volume: 03
Issue: 05 May 2025
Page No: 1587 - 1598

total efficiency of the vehicle in order to adjust the powertrain's setting for enhanced power and efficiency.

4. Simulation Set Up

In this configurationally arrangement, there is the use of an internal combustion engine (ICE) and an electric motor both tied in parallel to drive the vehicle's wheels. This category of a four-wheel drive system can allow the engine and motor to work either sequentially or simultaneously relative to the prevailing driving conditions and power intensity (Figure 3).

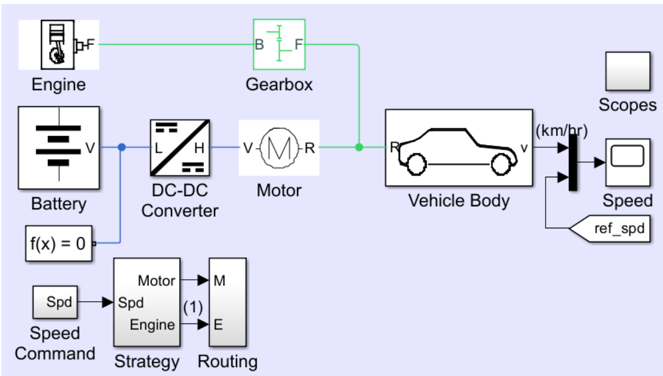


Figure 3 Simulation Set Up for eV Powertrain

The vehicle can operate on the electric motor alone when it is manoeuvring at low speeds or creeping in traffic congestion levels while at maximum speeds or during acceleration, both the ICE and the motor work hand in hand in generating power to the vehicle and avoiding wastage of fuel. This configuration provides optimizations and the usage of electricity in proper scenarios and still provides the oi power when necessary. The switching mechanism is effectively under the control of the control system to make sure that the operation is efficient. Parallel hybrid transmission systems are seen in many hybrid vehicles such as Toyota Prius and Honda insight because of its ability to provide the car with a good power output, fuel economy and low emission levels. The following is a simple example of the structure as implemented in a parallel hybrid transmission. There is a use of both electrical power and combustion engine power in parallel. The electrical torque is applied at the wheel axle and it can also be applied on the engine fly wheel. This test involves increasing the speed of the vehicle, keeping the high speed and returning to the same speed. Only electrical power is used to perform the maneuver, the combustion engine is only used to provide power to maintain the speed at which it was set. This paper develops mathematical models for losses for the motor, battery, and gearbox. This system-level model can be used to get an idea about the system performance and can help in the development of the power management strategy. It can be compared straight with the power split hybrid example sdl_hybrid_power_split and the series hybrid example sdl_hybrid_series. Refer Figures 4 to 12 and Table 1 and 2. Further a battery based electric vehicle model is developed to analyze above results.

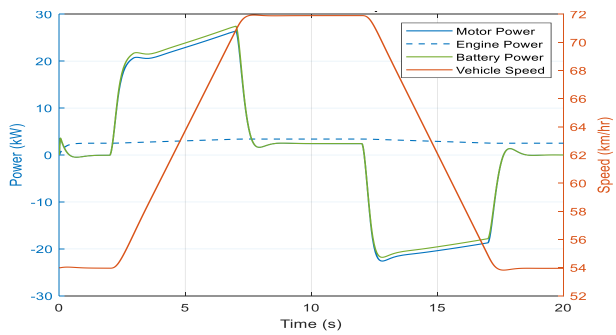


Figure 4 Power and Vehicle Speed

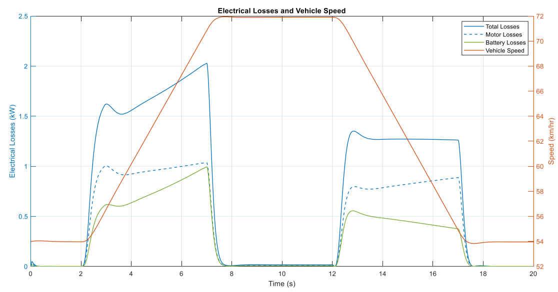


Figure 5 Electrical Losses and Vehicle Speed

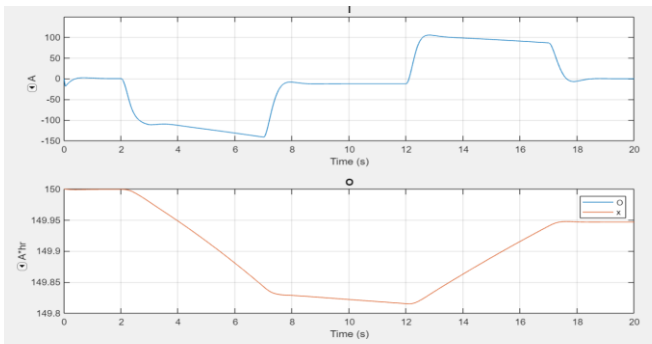


Figure 6 Battery Current Vs. Time

International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2025.0257

e ISSN: 2584-2854
Volume: 03
Issue: 05 May 2025
Page No: 1587 - 1598

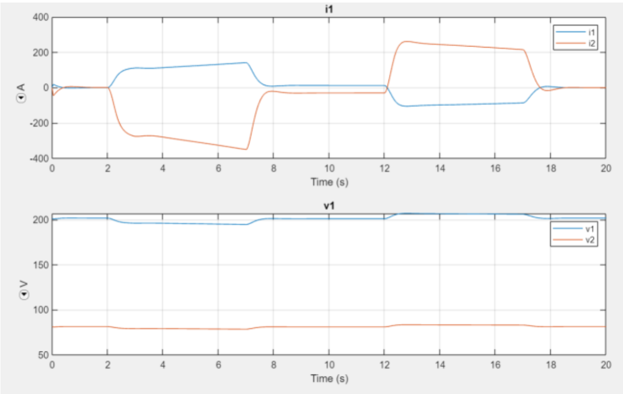


Figure 7 Battery Voltage Vs. Time

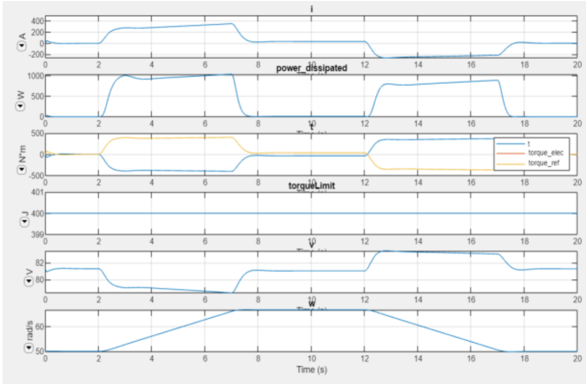


Figure 9 Motor Parameters

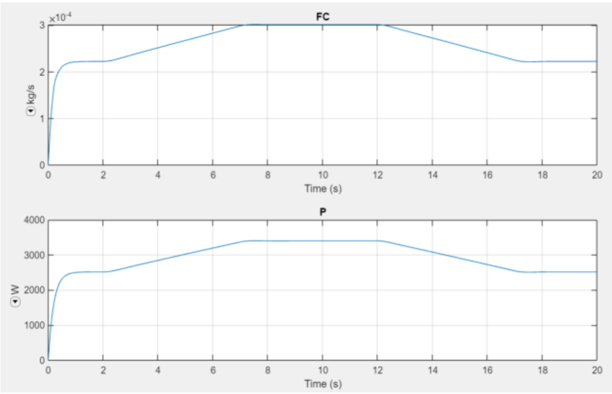


Figure 8 Battery Power Vs. Time

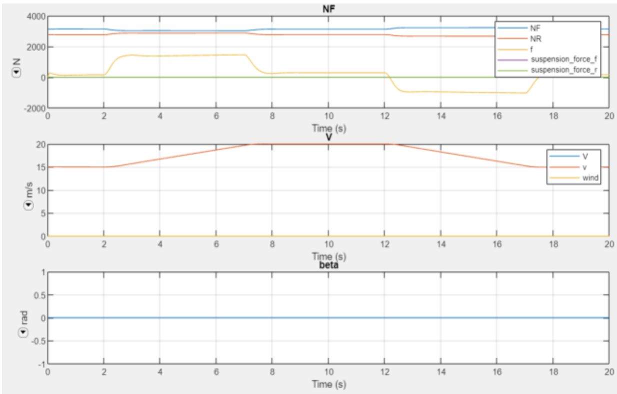


Figure 10 Vehicle Dynamics Parameters

Table 1 List of Parameters Required for Simulation using Matlab / Simulink

Battery Parameters	Nominal voltage	12 V
	Rated capacity	20 AH
	Initial stage of charge	100%
Vehicle parameters	Mass	100kg
	No of wheels per axle	2
	Horizontal Distance from CG to front axle	0.7m
	Horizontal Distance from CG to rear axle	0.7m
	CG height above ground	0.5m
	Gravitational Acceleration	$9.81 m/s^2$
	Drag coefficient	2
	Air Density	$1.18 kg/m^3$
Gear, differential and motor parameters	Carrier to drive shaft teeth ratio	4
	Follower to base teeth ratio	2
	Inductance	$12e^{-6}$ H
	No Load speed	6000 rpm
	Rated speed	5000 rpm
	Rated Load	1 kW
	Rated DC supply	24 V

International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2025.0257

e ISSN: 2584-2854
Volume: 03
Issue: 05 May 2025
Page No: 1587 - 1598

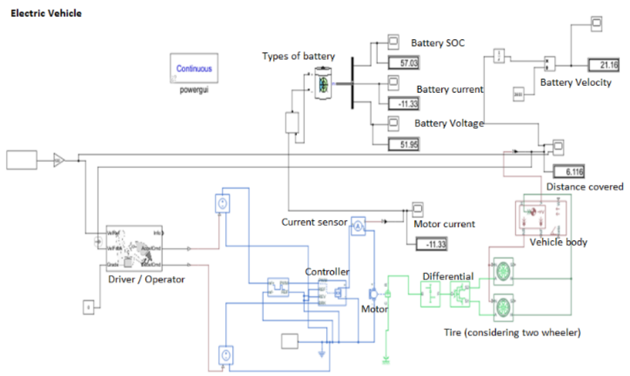
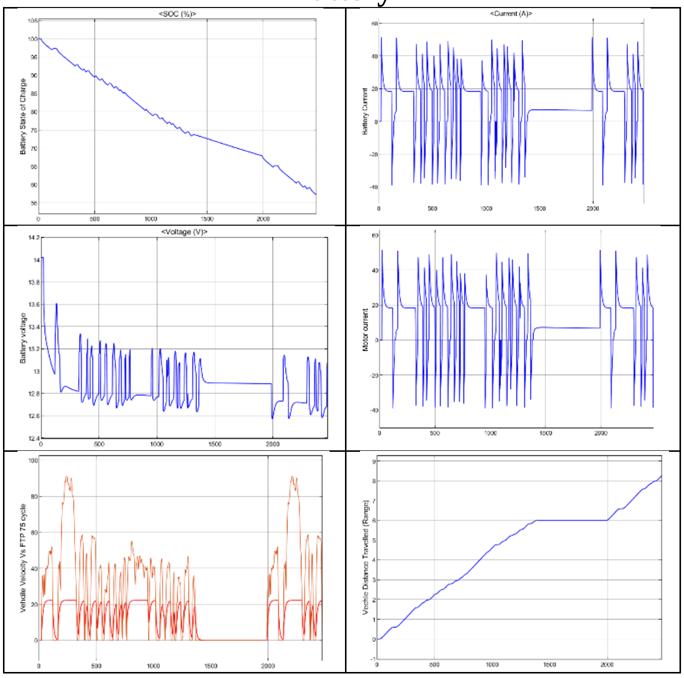


Figure 11 **Simulink model of E-Bicycle using Matlab / Simulink**

Table 2 **E-Bicycle Simulation Results with Li-Ion Battery**



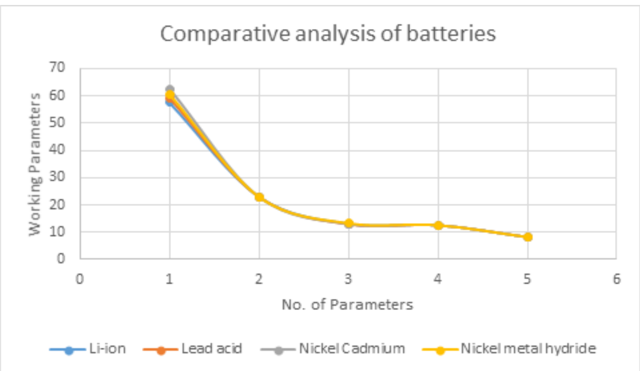


Figure 12 **Simulated Comparative Analysis of Different Battery Parameters**

5. Result Analysis

This takes place with the existing simulation results, whereby various aspects of the electric vehicle powertrain are produced and evaluated. They can involve torque and speed of the motor, batter SOC and the overall energy used by the motor. Torque and speed are used in the vehicle's acceleration and dynamic response while SOC is used to measure battery health and its range. The energy consumption information is then used in assessing how well the system is performing to inform the next steps towards improving the system's performance. The emission measurement and control of the powertrain can be assessed for various types of standardized drive cycles like NEDC, WLTP, FTP-75 to review its performance in the urban, highway, or a mixed environment. That is why these simulations are useful to control acceleration, energy consumption and state of charge at various loads like uphill or filled to maximum passengers. This guarantees that each powertrain boasts of efficiency when it is used in the real world. Sensitivity analysis refers to the process, which involves altering one or many component factors for instance efficiency of the motor, ratio of gears, or capacity of battery to ascertain their effects on totality of the system. This aids the designers in quickly identifying the key design parameters, so as to achieve the desired goals of powertrain efficiency, driving range and component endurance. It is also useful in decision making during buying of each component and the integration process of such systems. It is necessary to point out that the primary parameters, which can be visualized in case of the simulation data interpretation, are the time series plot, efficiency map, and the torque–speed curves. These are numerical plots of various aspects of the system with relation to time where one can observe the rates of speed, torque, SOC, and the energy consumed. Maps of efficiency indicate areas where the control and the parts should be achieving the most and where potential improvements can be made. In light of this view, the results from the evaluation simulation provide a general perspective of the complexity of the overall System and its function based on different operating conditions of the electric vehicle powertrain. Through torque output, vehicle speed, battery SOC and energy

International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2025.0257
e ISSN: 2584-2854
Volume: 03
Issue: 05 May 2025
Page No: 1587 - 1598

consumption, it is possible to determine the efficiency, the dynamic response and the energy control of the system. They support and justify explicit and unconscious decisions, which enlighten the designer about concepts for change. However, the design of an EV powertrain is done in such a manner that incorporates the aspects of efficiency and performance. For instance, achieving optimum efficiency reduces the maximum acceleration while getting the most drive power reduces power consumption and the car's range. Consumer demands and the technical feasibility of the design cannot be fully satisfied when it comes to motor size, gear ratios, and battery capacity. Nonetheless, simulation has its disadvantages: on the one hand, it is a rather efficient and un3bound approach to system evaluation. Lack of component modeling, assumptions about dynamic driving conditions, and elimination of variability are the possible causes of inaccuracy. These limitations must be admitted, and results should, in an ideal scenario, be substantiated with Factor 3 experimental/actual data. As such, the developed simulation model can help in size design of components, energy management strategies, and control algorithms. It enables one to test various configurations and control schemes of the system, which would mitigate the chances of developing a bad circuit, hence cuts down development time and cost.

Conclusions and Future Scope

This was done by simulating the electric vehicle powertrain in MATLAB/Simulink to have an elaborate view of the torque delivery, speed response, battery state of charge fluctuations, and or energy utilization under various dynamic modes of operations. The study also revealed how component level and system level affected efficiency and effectiveness of the model. It also drew attention towards the selection of parameters and drive cycles needed in order to attain a reasonable balance between the vehicle agility and energy consumption. MATLAB/Simulink was the optimal software for the construction of the EV powertrain because of its versatility as well as the effectiveness of it and the simulations performed with it. It also supports high speed prototyping, real-time emulation for control strategy and integration facility. This is because of the many pre-built toolboxes as well as the block libraries that can be modified to create electrical, mechanical and control subsystem that saves on time in terms of design and validation. By having a virtual environment before investing in physical one, the simulation model paves way for real life implementation, yes, by establishing an environment that will enable the powertrain configurations to be tested before being put into production. Such refinements and verifications will allow for the strategic determination of the choices of components, algorithms for controlling the electric vehicle, and energy management in actual electric vehicles. It is also suitable for future incorporation of intelligent systems and mixed structures, thus it is useful for both academic studies and practical use. The incorporation of AI or machine learning lets the control strategies in the simulation predict how the driver or traffic patterns of dynamic terrains will be like. These intelligent systems can increase energy productivity, control the power supply and the usage of batteries, and even optimize further the style of using cars through real time information. One more advantage of the introduced simulation model is the possibility of easy expansion to the more complicated schemes, such as hybrid or all-wheel-drive electrical vehicles. Thus, including more motor arrangements, energy supply systems, and drivetrain layouts helps to enhance vehicle configurations and their performance in traction force, power, and energy utilization.

References

[1]. Chakraborty, Sajib & Mazuela, Mikel & Tran, Duong & Corea Araujo, Javier & Lan, Yuanfeng & Alacano Loiti, Argiñe & Garmier, Patrice & Aizpuru, Iosu & Hegazy, Omar. (2020). Scalable Modelling Approach & Robust Hardware-in-the-Loop Testing of an Optimized Interleaved Bidirectional HV DC/DC Converter for Electric Vehicle Drivetrains. IEEE Access. PP. 1-1. 10.1109/ACCESS.2020.3004238.

[2]. Farhan Ahamed (2025). Electric Vehicle Powertrain modelling using Simulink.

[3]. Selvamuthukumar M, D.Vinay Kumar, Lokesh Madineni, "Electric Vehicle Modeling and Simulation Using MATLAB

SIMULINK", Recent Development in Multidisciplinary Science and Technological fields - Volume I.

[4]. Tomar, Vedant & Annamalai, Chitra & Krishnachaitanya, Daki & N S, Raghavendra & Indragandhi, V. & Raziasultana, W. (2021). Design of Powertrain Model for an Electric Vehicle using MATLAB/Simulink. 1-7. 10.1109/i-PACT52855.2021.9696518.

[5]. Tippannavar, Sanjay & M P, Madhu Sudan & S D, Yashwanth. (2023). Design, Modelling and Optimization of an Electric Vehicle (EV) and Comparison of Performance for Different drive Cycles using MATLAB & SIMULINK. International Journal of Innovative Research in Advanced Engineering. 10. 58-66. 10.26562/ijirae.2023.v1003.03.

[6]. Sanjay S Tippannanavar, and Madhu Sudan, "Design, Modelling and Optimization of an Electric Vehicle (EV) and Comparison of Performance for Different drive Cycles using MATLAB & SIMULINK", IJIRAE - International Journal of Innovative Research in Advanced Engineering, https://doi.org/10.26562/ijirae.2023.v1003.03.

[7]. Inaganti Anand Babu, Belle Ganesh, Selvamuthukumar M, "Electric Vehicle Modeling & Simulation Using MATLAB SIMULINK", YMER || ISSN : 0044-0477, VOLUME 21 : ISSUE 6 (June) – 2022, http://ymerdigital.com, Page No:848-857.

[8]. Wang, X.; Liu, S.; Ye, P.; Zhu, Y.; Yuan, Y.; Chen, L. Study of a Hybrid Vehicle Powertrain Parameter Matching Design Based on the Combination of Orthogonal Test and Cruise Software. Sustainability 2023, 15, 10774. https://doi.org/10.3390/su151410774.

[9]. I Duma, A Molea, N Cordoș, H Cărăușan, N Burnete, I Barabás, A Todoruț and B M Jurchiș, "Possibilities to evaluate the vehicle's accelerations through MATLAB Simulink simulations" ESFA-2023 IOP Conf. Series: Materials Science and Engineering 1303 (2024) 012040 IOP Publishing doi:10.1088/1757-899X/1303/1/012040.

[10]. Zhang, Y.; Zhao, C.; Dai, B.; Li, Z. Dynamic Simulation of Permanent Magnet Synchronous Motor (PMSM) Electric Vehicle Based on Simulink. Energies 2022, 15, 1134. https://doi.org/10.3390/en15031134.

[11]. R. J. Huang et al., "High secondary aerosol contribution to particulate pollution during haze events in China," Nature, vol. 514, no. 7521, p. 218, 2014.

[12]. F. W. Geels, "Disruption and low-carbon system transformation: Progress and new challenges in Socio-technical transitions research and the Multi-Level Perspective," Energy Research & Social Science,vol 34, pp. 224-231, 2017.

[13]. C. Capasso and O. Veneri, "Experimental analysis on the performance of lithium-based batteries for road full electric and hybrid vehicles," Applied Energy, vol. 136, pp. 921-930, 2014.

[14]. B. Dunn and J. M. Tarascon, "Electrical energy storage for the grid: a battery of choices," Science, vol. 334, no. 6058, pp. 928-35, 2011.

[15]. L. Ahmadi, S. B. Young, M. Fowler, R. A. Fraser, and M. A. Achachlouei, "A cascaded life cycle: reuse of electric vehicle lithium-ion battery packs in energy storage systems," International Journal of Life Cycle Assessment, vol. 22, no. 1, pp. 1-14, 2015.

[16]. K. Richa, C. W. Babbitt, and G. Gaustad, "Eco-Efficiency Analysis of a Lithium-Ion Battery Waste Hierarchy Inspired by Circular Economy," Journal of Industrial Ecology, no. 3, pp 715-730, 2017.

[17]. R. Gogoana, M. B. Pinson, M. Z. Bazant, and S. E. Sarma, "Internal resistance matching for parallel-connected lithium-ion cells and impacts on battery pack cycle life," Journal of Power Sources, vol. 252, pp. 8-13, 2014.

[18]. J. Liu, G. Li, and H. K. Fathy, "A Computationally Efficient Approach for Optimizing Lithium-Ion Battery Charging,"

International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2025.0257
e ISSN: 2584-2854
Volume: 03
Issue: 05 May 2025
Page No: 1587 - 1598

Journal of Dynamic Systems Measurement & Control, vol. 138, no. 2, 2015.

[19]. N. Liu et al., "A pomegranate-inspired nanoscale design for large-volume-change lithium battery anodes," Nature Nanotechnology, vol. 9, no. 3, p. 187, 2014.

[20]. Y. Zheng et al., "Cell state-of-charge inconsistency estimation for LiFePO4 battery pack in hybrid EVs using mean- difference model," Applied Energy, vol. 111, no. 11, pp. 571-580, 2013.

[21]. F. Sun and R. Xiong, "A novel dual-scale cell state-of-charge estimation approach for series-connected battery pack used in EVs," Journal of Power Sources, vol. 274, pp. 582-594, 2015.

[22]. L. C. Casals, B. A. García, F. Aguesse, and A. Iturrondobeitia, "Second life of electric vehicle batteries: relation between materials degradation and environmental impact," International Journal of Life Cycle Assessment, vol. 12, no. 4, pp. 1-12, 2015.

[23]. H. Ambrose, D. Gershenson, A. Gershenson, and D. Kammen, "Driving rural energy access: a second-life application for electric-vehicle batteries," Environmental Research Letters, vol. 9, no. 9, p. 094004, 2014.

[24]. C. Koch-Ciobotaru, A. Saez-De-Ibarra, E. Martinez-Laserna, D. I. Stroe, M. Swierczynski, and P. Rodriguez, "Second life battery energy storage system for enhancing renewable energy grid integration," in Energy Conversion Congress and xposition, 2015, pp. 78-84.

[25]. E. Martinez-Laserna et al., "Evaluation of lithium-ion battery second life performance and degradation," in Energy Conversion Congress and Exposition, 2017.

[26]. L. C. Casals, B. A. García, F. Aguesse, and A. Iturrondobeitia, "Second life of electric vehicle batteries: relation between materials degradation and environmental impact," International Journal of Life Cycle Assessment, vol. 12, no. 4, pp. 1-12, 2015.