PROJECT REPORT

On

ELECTRICAL VEHICLE MODELING USING MATLAB

B .TECH 4TH SEMESTER ELECTRICAL ENGINEERING

Submitted by

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DECLARATION

We hereby certify that the work which is being presented in this project report entitled "Electric vehicle modelling in MATLAB", in partial fulfillment of requirements for the 4th semester of degree of BACHELOR OF TECHNOLOGY in ELECTRICAL ENGINEERING, submitted to the Department of Electrical Engineering, Faculty of Engineering and Technology, J.C. Bose University of Science and Technology, YMCA, Faridabad, Haryana-121006 is an authentic record of our work carried out during period from February 2024 to May 2024, under the supervision of Dr. Shakuntla . We have not submitted the matter presented in this project report to any other University/Institute for the award of B.Tech. or any degree or diploma

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CERTIFICATE

This is to certify that the project entitled "Electric vehicle modelling in MATLAB" submitted to Department of Electrical Engineering, Faculty of Engineering and Technology, J.C. Bose University of Science and Technology, YMCA, Faridabad, Haryana-121006 by Dr Shakuntla in partial fulfilment of the requirement for the 4th semester of degree of BACHELOR OF TECHNOLOGY in ELECTRICAL ENGINEERING, is a bonafide work carried out by them under my supervision and guidance. This project work comprises of original work and has not been submitted anywhere else for any other degree to the best of my knowledge.

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OBJECTIVE :

The objective of electrical vehicle modeling in MATLAB is to stimulate and analyze the performance of electrical vehicle which involves creating mathematical models that represent various aspects of an electrical vehicle such as battery , motor , controller , power converter and analysis of electrical vehicle according to its drive cycle .

By using MATLAB , different scenarios can be optimized and various can be created which helps in analyzing factors like energy efficiency , range and overall performance in accordance with different drive inputs .

Electric vehicles are becoming promising alternatives to be remedy for urban air pollution, green house gases and depletion of the finite fossil fuel resources (the challenging triad) as they use centrally generated electricity as a power source. It is well known that power generation at centralized plants are much more efficient and their emissions can be controlled much easier than those emitted from internal combustion engines that scattered all over the world. Additionally, an electric vehicle can convert the vehicle's kinetic energy to electrical energy and store it during the braking and coasting.

All the benefits of electrical vehicles are starting to justify, a century later, attention of industry, academia and policy makers again as promising alternatives for urban transport. Nowadays, industry and academia are striving to overcome the challenging barriers that block widespread use of electric vehicles. Lifetime, energy density, power density, weight and cost of battery packs are major barriers to overcome. However, modeling and optimization of other components of electric vehicles are also as important as they have strong impacts on the efficiency, drivability and safety of the vehicles. In this sense there is growing demand for knowledge on electric vehicle components. Electric vehicles are by many seen as the cars of the future as they are highly efficient, produces no local pollution, are silent, and can be used for power regulation by the grid operator. However, electric vehicles still have critical issues which need to be solved. The three main challenges are limited driving range, long charging time, and high cost. The three main challenges are all related to the battery package of the car. The battery package should both contain enough energy in order to have a certain driving range and it should also have a sufficient power capability for the accelerations and decelerations. In order to be able to estimate the energy consumption of an electric vehicles it is very important to have a proper model of the vehicle. The model of an electric vehicle is very complex as it contains many different components, e.g., transmission, electric machine, power electronics, and battery. Each component needs to be modeled properly in order prevent wrong conclusions. The design or rating of each component is a difficult task as the parameters of one component affect the power level of another one. There is therefore a risk that one component is rated inappropriate which might make the vehicle unnecessary expensive or inefficient. The focus in this chapter will be on the modeling and design of the power system of a battery electric vehicle .

Nowadays the air pollution and economical issues are the major driving forces in developing electric vehicles (EVs). In recent years EVs and hybrid electric vehicles (HEVs) are the only alternatives for a clean, efficient and environmentally friendly urban transportation system . The electric vehicle (EV) appears poised to make a successful entrance to the personal vehicle mass market as a viable alternative to the traditional internal combustion engine vehicles (ICE). Recent advances in battery technology indicate decreasing production costs and increasing energy densities to levels soon acceptable by broad consumer segments. Moreover, excluding the generation of the electricity, EVs emit no greenhouse gases and could contribute to meeting the strict CO2 emission limits necessary to dampen the effect of global warming. Several countries around the world have therefore initiated measures like consumer tax credits, research grants or recharging station subsidies to support the introduction of the EV. Finally, the success alternative vehicles like the Toyota Prius Hybrid proves a shift in consumer interest towards cleaner cars with lower operating costs . Nonetheless, the EV will first need to overcome significant barriers that might delay or even prevent a successful mass market adoption.

Contemporary fuel vehicles have become the most important means of transportation for people. Although it makes transportation extremely convenient, it is a test of the earth's limited resources. In addition, fuel vehicles cause greater pollution in the air due to the bits and pieces of exhaust emissions, affecting the health of all people. As a result, electric vehicles are becoming their replacement. Because their prices are more affordable and less harmful to the environment, especially in recent years, such as Tesla and other large companies, electric vehicles are also slowly becoming popular. With the expansion of the field of electric vehicles, various data points have also been paid attention to and tested by society. At this stage, China has developed assisted driving and unmanned driving technologies. In the Internet era, the development of pure electric vehicles should also seek a broader space. Pure electric vehicles and distributed energy, intelligent transportation, and 5G communication technology can develop in synergy, paving the way for the development of pure electric vehicles in China and laying a good foundation for the development of pure electric vehicles .

The whole Simulation model of Simulink is easy to update the data, so the characteristics of electric vehicles, such as basic mechanism, performance parameters, and feedback mechanism of key links, can be corrected and debugged in time. Through the model design of this case, the design, modeling, simulation, and testing in the development process of an automotive embedded system can be organically combined to form a relatively complete development mode

ABSTRACT :-

In MATLAB, Electric Vehicle (EV) modeling typically involves creating multi-domain simulations that consider the interactions between various components. These components may include the main vehicle body, battery model, electric motor dynamics, H-bridge, current sensors ,controlled voltage sources ,controlled current sources, controlled PWM voltage etc. being some of the main components. .Key aspects of EV modeling in MATLAB include:

- Battery Modeling: Creating models that represent the behavior of the battery, considering factors like state of charge, voltage, current, and temperature analyzing various drive cycle inputs given to it.
- Electric Motor Modeling: Representing the electric motor and its controller to analyze power conversion, torque generation, and overall drive train performance.
- Vehicle Dynamics: Designing a vehicle body as a prototype to original vehicle by making all connections within the MATLAB considering its required features which are most efficient in running the vehicle while alongside analyzing other drive inputs and outputs, simulating the overall vehicle dynamics, including aerodynamics, rolling resistance and analyzing its functioning taking into consideration its weight and center of mass.
- Control System Design: Developing control algorithms for managing power distribution so that instead of having a constant speed, the speed of electric vehicle can be varied in accordance with drive inputs with the help of power converters like H-Bridge with regenerative braking, and overall vehicle performance otherwise connecting battery directly to motor unables the driver to control the vehicle speed
- Thermal Analysis: Evaluating the thermal behavior of the components to ensure they operate within safe temperature ranges creating a system involving a proper heat dissipation preventing wear to the vehicle parts as a result of which ensuring optimal performance , expending component life span which makes it cost efficient for the user and maintaining overall safety of the vehicle.
- Energy Efficiency and Range Estimation: Assessing the energy efficiency of the electric vehicle as the very approach of designing electric vehicle is based on creation of energy efficient and sustainably supported vehicle systems in today's world and estimating its range under different driving conditions with varying energy inputs at different speeds and time instances of the drive cycle

So in MATLAB we are able to simulate real-world scenarios, and refine the design of electric vehicles before physical prototypes are built, helping to accelerate the development process and improve the overall performance of electric vehicle .

BLOCK DIAGRAM:-

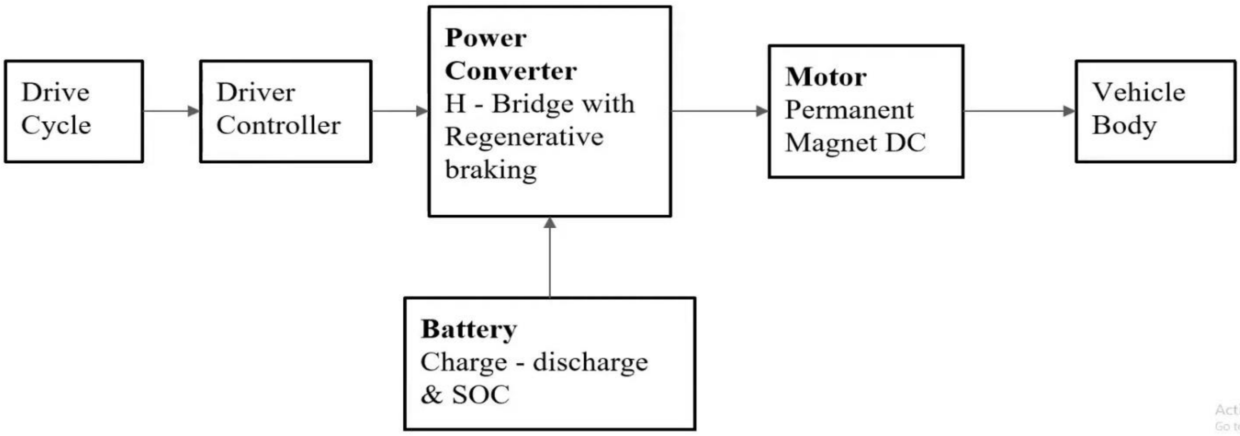


Figure 1: Block diagram

This block diagram depicts the way in which various electrical vehicle parts interact while they run. The drive cycle is given as an input to driver controller which interacts with power converter and battery which supplies vehicle with energy to operate where permanent magnet DC motor is a connecting link between vehicle body and power converter.

<u>STIMULATION DIAGRAM</u>:

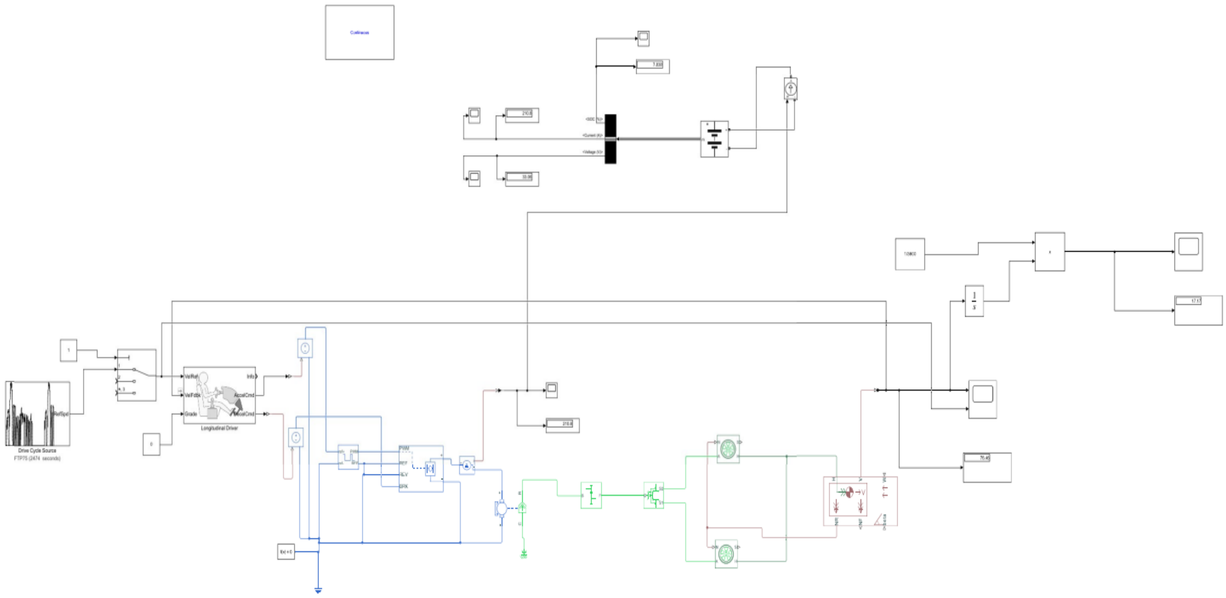


Figure 2: Simulation diagram

LITERATURE :-

The electrical vehicles are coming up as an substitute to petrol or diesel run cars because now-a-days as the focus is on pollution free vehicles that supports sustainable development .

Traditional cars or petrol-run car typically consists of an internal combustion engine, fuel system, ignition system, transmission, and exhaust system. The engine combusts a mixture of air and fuel in cylinders, generating power to drive the vehicle and fuel system includes components like a fuel tank, pump, and injectors. The ignition system ignites the fuel-air mixture, and the transmission transfers power to the wheels. The exhaust system removes and filters emissions produced during combustion while internal combustion engine is the core component, converting fuel into mechanical power. Comprising a fuel tank, pump, and injectors, it delivers fuel to the engine and ignition system is responsible for igniting the fuel-air mixture in the engine's cylinders. Transmitter transfers power from the engine to the wheels, allowing the car to move. Exhaust System removes and filters emissions produced during the combustion process. Cooling System manages engine temperature to prevent overheating, typically using a radiator and coolant. Battery provides electrical power for starting the engine and operating various electrical components. Alternator Charges the battery and supplies power to the car's electrical systems while the engine is running. Suspension System absorbs shocks and ensures stability, improving ride comfort and handling. Brake System enables deceleration and stopping. Steering System facilitates vehicle control, often using a combination of a steering wheel, column, and power steering. Electrical System manages various electrical components, including lights, sensors, and the car's onboard computer. But in all of this overall running of the petrol fueled cars produces a lot of pollutants that are released and also petrol used is a non-renewable energy providing source , so as the matter of fact this type of cars require improvement.

This creates a need for investigating the seamless integration of renewable energy resources to cater energy requirements of electric vehicle to replace petrol run typical cars which contributes in reducing carbon emissions , dependences on fossil fuels and increase overall environmental sustainability.

The electrical vehicles which are powered by electrically run motors are the best alternative available present today and EV designing is done most feasibly using MATLAB software .

In the electrical cars, electric Motor replaces the traditional internal combustion engine, converting electrical energy into mechanical power. Battery Pack stores electrical energy for the electric motor, usually made up of lithium-ion cells. Inverter converts DC (direct current) from the battery to AC (alternating current) for the electric motor. Charger manages the charging process, converting AC power from an external source to DC for the battery. Regenerative Braking System recovers energy during braking and converts it back into electrical energy to recharge the battery .Electric Vehicle Controller manages the flow of electrical energy between the battery, motor, and other components . Thermal Management System regulates the temperature of the battery and other critical components to optimize performance and longevity . Onboard Charging System allows the vehicle to be charged from external power sources like charging stations or home outlets .Electric Power Steering provides assistance to the driver in steering the vehicle. Electric HVAC System manages heating, ventilation, and air conditioning using electrical power. Infotainment System includes the touchscreen display, audio system, and other entertainment features powered by the vehicle's electrical system. Electric Brake System coordinates with regenerative braking and traditional braking mechanisms for deceleration and stopping. So electrical cars are a better energy saving product with moderanisation integrated within its features.

Basic working of electrical vehicle is as follow :

Battery Pack: It provides electrical energy to power the vehicle which is typically composed of multiple lithium-ion battery cells connected in series and parallel. Other batteries like nickel-cadmium , lead -acid batteries are also popular but we prefer lithium-ion battery due to its specific energy and life cycle. This battery pack is managed by a Battery Management System (BMS) for monitoring individual cell voltages, temperatures, and state of charge to ensure safe operation and optimize performance.

Converters: They converts DC power from the battery into AC power to drive the electric motor. They includes an inverter to convert DC to AC, and sometimes a DC-DC converter for auxiliary systems. Function of the converters is controlled by sophisticated systems to regulate power delivery and ensure smooth operation.

Electric Motor: They converts electrical energy into mechanical energy to drive the vehicle. Typically a three-phase AC induction motors are prefered due to their efficiency but for smaller versions of EVs DC motors can also be used. They are controlled by motor control algorithms to manage torque, speed, and efficiency.

Transmission System: In many EVs, a single-speed transmission is used due to the wide torque range of electric motors. Some EVs, especially hybrids, may have multi-speed transmissions for improved efficiency or performance.

Regenerative Braking: This method is employed as it recaptures energy during braking and deceleration to recharge the battery. When the driver lifts off the accelerator or applies the brakes, the motor acts as a generator, converting kinetic energy back into electrical energy.

Vehicle Control Systems: They manage the overall operation of the vehicle, including acceleration, braking, and steering. This system coordinate the interactions between the electric motor, battery, brakes, and other systems for optimal performance, efficiency, and safety.

Thermal Management System: It maintains optimal operating temperatures for the battery, motor, power electronics, and other components. It also helps to maximize efficiency, extend component lifespan, and ensure safe operation.

Charging System : They enables recharging of the battery from an external power source. Includes onboard charging electronics and connectors compatible with various charging standards (e.g., AC charging, DC fast charging).

Driver Interface and Controls: This interface provides the driver with information about vehicle status, battery charge level, range, and other essential metrics. It also includes controls for adjusting driving modes, regenerative braking levels, and other vehicle settings.

Overall, the workings of an electric vehicle involve a complex interplay of electrical, mechanical, and control systems, all orchestrated to provide efficient, reliable, and environmentally friendly transportation.

COMPONENTS :-

DRIVE CYCLE SOURCE

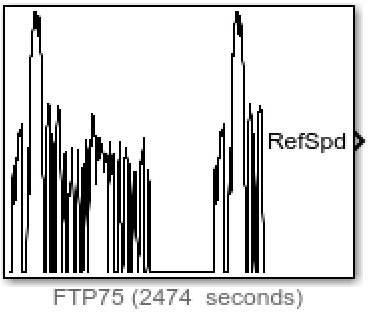


figure 3 : Drive cycle source

The Drive Cycle Source block generates a standard or user-specified longitudinal drive cycle. The block output is the vehicle longitudinal reference speed as a function of time, along with gear shift schedule . The drive cycle can be used for:

1.To predict the required engine torque and fuel consumption for a vehicle to follow a specified speed profile, with a given gear shift schedule.

2.To produce realistic velocity and shift schedules for closed loop acceleration and braking commands for vehicle control and plant models and to study, tune, and optimize vehicle control, system performance, and system robustness in covering multiple drive cycles.

3.To identify faults outside the tolerances specified by standardized tests.

H- BRIDGE :

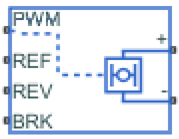


figure 4 :H-bridge

The H-Bridge block represents an H-bridge motor driver. It is a type of electronic circuit that is widely used in controlling the direction and speed of dc motors including those used in electric vehicles . A H-Bridge consist of four switches . by turning on the appropriate combination of switches the H-bridge can control the direction of current flow through the motor .

Pulse Width Modulation is commonly used to control the speed of motor , by varying the duty cycle of PWM signal, the effective voltage applied to motor is adjusted thereby controlling its speed . Higher duty cycle results in higher average voltage and faster motor speed while lower duty cycle results in lower average voltage and slower speed .

In electric vehicles, H-bridges is used for regenerative braking. When the motor acts as a generator during braking, the H-bridge can redirect the generated current back into the battery for recharging by appropriately controlling the switches.H-bridges often include circuitry for overcurrent protection, short-circuit protection, and thermal protection to ensure safe operation. Control signals for the H-bridge switches are generated by microcontrollers or motor control ICs, which monitor various parameters such as motor speed, torque, and temperature to adjust the control signals accordingly. Efficient operation of the H-bridge is crucial for minimizing power losses and maximizing motor performance .Proper design considerations, such as selecting appropriate switching devices, minimizing switching losses, and implementing effective control strategies, are essential for achieving high efficiency and optimal performance. Overall, H-bridges play a vital role in the control of DC motors in electric vehicles, enabling precise control of both direction and speed while also facilitating regenerative braking for improved energy efficiency.

MULTIPORT SWITCH :

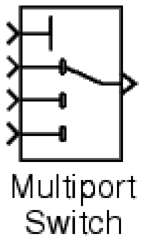


figure 5: Multiport switch

The Multiport Switch block determines which of several inputs to the block passes to the output. The block bases this decision on the value of the first input. The first input is the control input and the remaining inputs are the data inputs. The value of the control input determines which data input passes to the output .Setting number of data ports to 1, the block behaves as an index selector or index vector and not as a multiport switch while setting number of data ports to an integer greater than 1, the block behaves as a multiport switch. The block output is the data input that corresponds to the value of the control input. If at least one of the data inputs is a vector, the block output is a vector. In this case, the block expands any scalar inputs to vectors. If all the data inputs are scalar, the output is a scalar.

BATTERY :

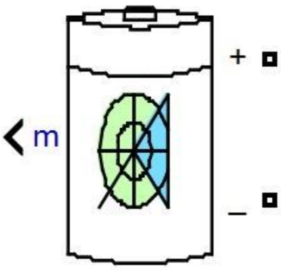


figure 6: Battery

In an electric vehicle (EV), the battery serves as the primary energy storage device, supplying electrical power to drive the vehicle's motor. The battery stores electrical energy in the form of chemical energy .It provides the energy required to power the electric motor for propulsion .

Lithium-ion batteries are the most common type used in EVs due to their high energy density, relatively long lifespan, and fast charging capability. Other battery chemistries, such as lithium iron phosphate (LiFePO4), are also used for specific applications, offering advantages like enhanced safety or lower cost. The battery is typically organized into a pack consisting of multiple individual cells connected in series and parallel configurations .The pack is designed to meet the voltage and capacity requirements of the vehicle, balancing factors like energy density, weight, and available space. The capacity of the battery pack, measured in kilowatt-hours (kWh), determines the amount of energy it can store.

The range of an EV depends largely on the battery capacity, along with factors like vehicle efficiency, driving conditions, and temperature. EV batteries can be charged from external power sources, such as home charging stations or public charging infrastructure. Charging methods include slow charging (AC charging at lower power levels) and fast charging (DC charging at higher power levels), with charging times ranging from several hours to less than an hour, depending on the charging rate and battery capacity.

The BMS monitors and manages the performance, health, and safety of the battery pack. It regulates charging and discharging processes, balances cell voltages, and protects against overcharging, over-discharging, and overheating. The BMS also provides data on battery state of charge (SoC), state of health (SOH), and remaining range to the vehicle's control system and dashboard display. Proper thermal management is essential to maintain the battery within its optimal operating temperature range. Cooling systems, such as liquid or air cooling, help dissipate heat generated during charging and discharging, preventing thermal runaway and degradation of battery performance and lifespan. Over time, EV batteries experience gradual capacity degradation and efficiency loss due to factors like usage patterns, temperature variations, and aging. Battery manufacturers and vehicle manufacturers implement strategies to mitigate degradation and extend battery lifespan, such as thermal management, charge control algorithms etc. So the battery in an electric vehicle plays a critical role in providing energy for propulsion, determining the vehicle's range and performance, and influencing factors like charging time, lifespan, and overall cost of ownership. Advances in battery technology continue to drive improvements in EV range, efficiency, and affordability, contributing to the widespread adoption of electric vehicles as a sustainable transportation solution.

Charge and Discharge Characteristics of battery :

The circuit parameters can be modified to represent a specific battery type and its discharge characteristics. A typical discharge curve consists of three sections.

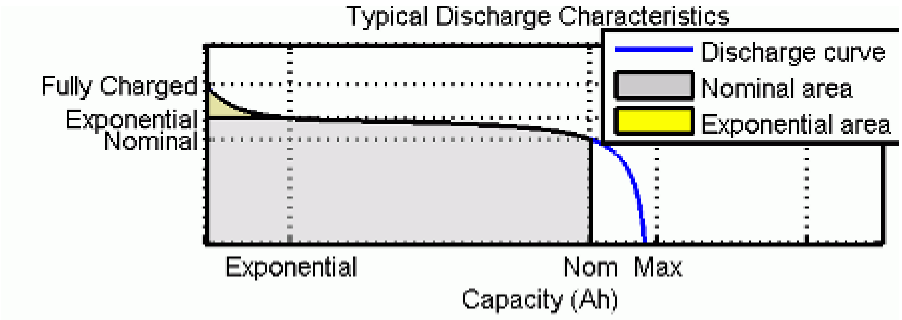


figure 7: Discharge characteristics

The first section represents the exponential voltage drop when the battery is charged. The width of the drop depends on the battery type. The second section represents the charge that can be extracted from the battery until the voltage drops below the battery nominal voltage. Finally, the third section represents the total discharge of the battery, when the voltage drops rapidly.

When the battery current is negative, the battery recharges, following a charge characteristic.

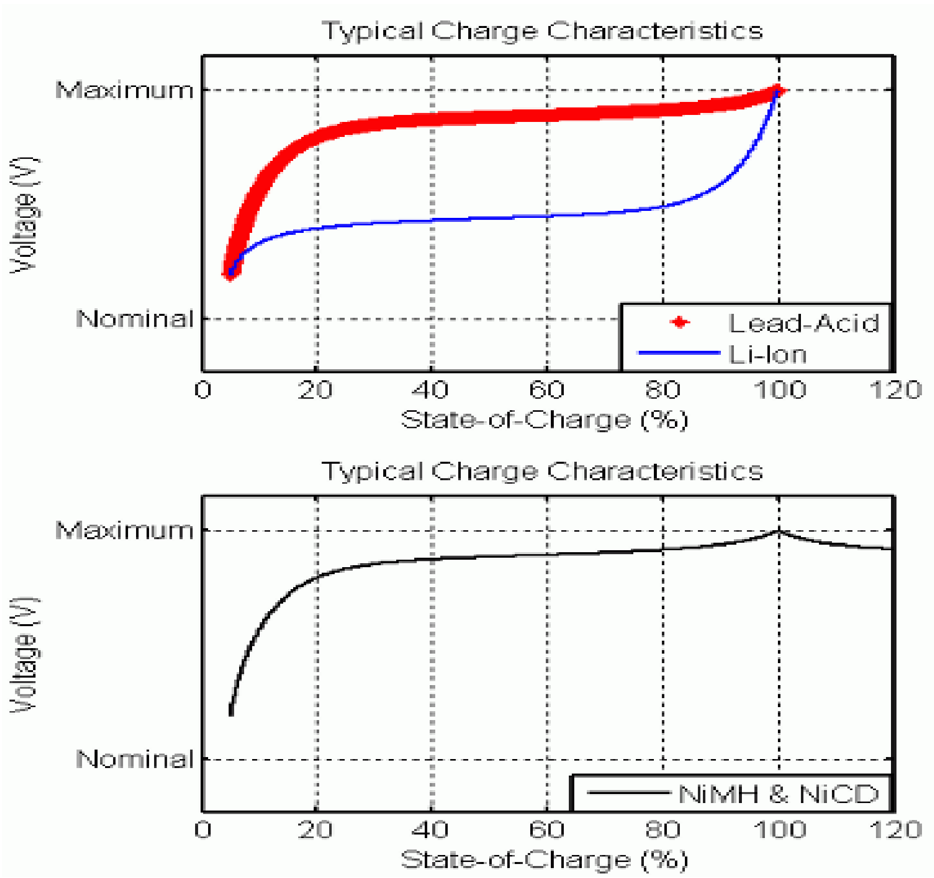


Figure 8 Charge characteristics

The model parameters are derived from the discharge characteristics. The discharging and charging characteristics are assumed to be the same.

The Exp(s) transfer function represents the hysteresis phenomenon for the lead-acid, nickel-cadmium (NiCD), and nickel-metal hydride (NiMH) batteries during the charge and discharge cycles. The exponential voltage increases when a battery is charging, regardless of the battery's state of charge. When the battery is discharging, the exponential voltage decreases immediately.

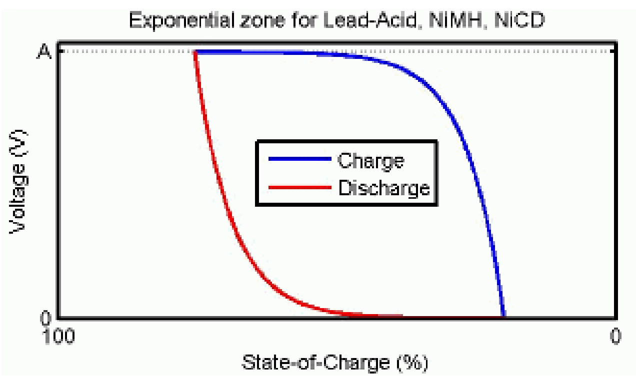


figure 9 State of charge

The state of charge (SOC) for a battery is a measure of battery's charge, expressed as a percent of the full charge. Response time of the battery, in s, at 95% of the final value

TIRE(MAGIC FORMULA)

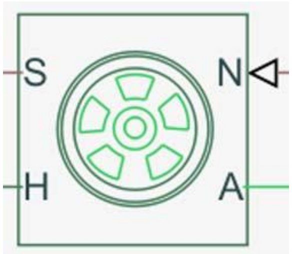


figure 10: Tire

The Tire (Magic Formula) block represents a tire with longitudinal behavior given by the Magic Formula which is an empirical equation based on four fitting coefficients. Tire dynamics can be modeled under constant or variable pavement conditions. The longitudinal direction of the tire is the same as its direction of motion as it rolls on pavement. This block is a structural component based on the Tire-Road Interaction (Magic Formula) block. To increase the fidelity of the tire model, properties such as compliance, inertia, rolling resistance, and varying effective rolling radius can be considered while designing it. However, these properties increase the complexity of the tire model and can slow down simulation.

Tires play a crucial role in electric vehicles (EVs) just as they do in traditional internal combustion engine vehicles. Tires significantly influence the overall energy efficiency of an EV. Rolling resistance, which is the resistance encountered as the tires roll over the road surface, can impact energy consumption. Low rolling resistance tires are often used in EVs to minimize energy losses and improve range. Tires interact with regenerative braking systems in EVs. During braking, the tires provide traction to the road surface, allowing the vehicle's regenerative braking system to capture kinetic energy and convert it into electrical energy to recharge the battery. Tire grip and traction characteristics affect the effectiveness of regenerative braking . EVs are generally quieter than internal combustion engine vehicles, but tire noise can still contribute to overall cabin noise levels. Tire design, tread pattern, and composition can influence noise levels, and manufacturers often prioritize noise reduction in EV tire development. EVs tend to be heavier than conventional vehicles due to the weight of the battery pack. Tires must be designed to support the increased vehicle weight while maintaining performance and safety. The tire's load-carrying capacity and sidewall strength are crucial factors in handling the weight of EV. They also play a critical role in providing grip and stability, especially during acceleration and cornering. Tire design, including tread pattern, compound, and sidewall stiffness, influences handling characteristics and traction. As they can heat up during high-speed driving or under heavy loads , proper tire selection and inflation pressure management are important for maintaining optimal tire temperature and performance. Overheating can lead to increased rolling resistance and reduced tire life. EVs may have different tire wear characteristics compared to internal combustion engine vehicles due to differences in weight distribution and driving patterns. Regular tire maintenance, including rotation, alignment, and proper inflation, is essential for maximizing tire lifespan and ensuring safe and efficient operation of the vehicle .

DC MOTOR :-

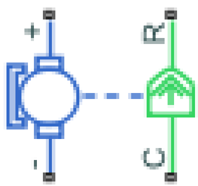
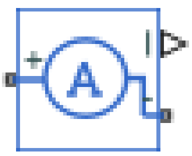


figure 10: Dc motor

DC (direct current) motors have been historically used in electric vehicles (EVs) for propulsion due to their simplicity, reliability, and controllability. Propulsion : DC motors are commonly used as traction motors in EVs to drive the wheels and provide propulsion . They convert electrical energy from the battery into mechanical energy to propel the vehicle forward or backward. DC motors can achieve high efficiency over a wide range of operating conditions . Their efficiency can be further enhanced by utilizing regenerative braking, where the motor acts as a generator during braking, converting kinetic energy back into electrical energy to recharge the battery. These motors are relatively easy to control, making them suitable for various driving conditions and applications . Speed and torque can be controlled by adjusting the voltage applied to the motor using electronic speed controllers (ESCs) or pulse-width modulation (PWM) techniques .DC motors provide high torque at low speeds, making them well-suited for urban driving and stop-and-go traffic conditions typical in city driving .This characteristic enhances acceleration performance, providing a responsive driving experience.DC motors are often more cost-effective than alternative motor types, such as AC (alternating current) induction motors or permanent magnet synchronous motors (PMSMs).They have simpler construction and fewer components, leading to lower manufacturing costs. DC motors can be easily integrated with various types of battery systems commonly used in EVs, such as lithium-ion batteries. Their compatibility with battery voltage ranges allows for flexible system design and integration. DC motors have a long history of use in automotive applications and are known for their reliability and durability. They have fewer moving parts compared to some other motor types, reducing the likelihood of mechanical failure and simplifying maintenance .Despite these advantages, DC motors also have limitations, such as limited efficiency at high speeds and the need for brush maintenance in brushed DC motors. As a result, newer EV designs often utilize alternative motor types, such as AC induction motors or PMSMs, which offer improved efficiency and performance characteristics. However, DC motors continue to be used in certain EV applications where their simplicity, cost-effectiveness, and controllability are advantageous.

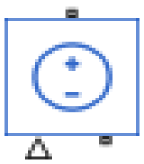
CURRENT SENSOR



The Current Sensor block represents an ideal current sensor, that is, a device that converts current measured in any electrical branch into a physical signal proportional to the current.

Figure 11: Current sensor

CONTROLLED VOLTAGE SOURCE



The Current Sensor block represents an ideal current sensor, that is, a device that converts current measured in any electrical branch into a physical signal proportional to the current.

Figure 12: Controlled voltage source

CONTROLLED PWM VOLTAGE SOURCE

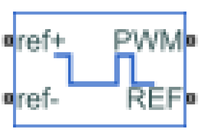
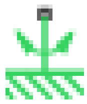


Figure -13: Controlled PWM voltage source

The Controlled PWM Voltage block represents a pulse-width modulated (PWM) voltage source. It is possible to model electrical or physical signal input ports by setting the Modeling option parameter to either between output high and output low states:

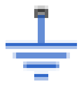
MECHANICAL ROTATIONAL REFERENCE:-



The Mechanical Rotational Reference block represents a reference point, or frame, for mechanical rotational ports. All rotational ports that are rigidly clamped to the frame must be connected to a Mechanical Rotational reference .

Figure -14: Mechanical rotational reference

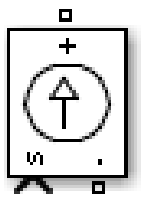
ELECTRICAL REFRENCE :-



The electrical reference block represents an electrical ground in MATLAB Simulink . a model with electrical elements must contain atleast one electrical reference block .

Figure 15: Electrical reference

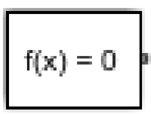
CONTROLLED CURRENT SOURCE:-



The Controlled Current Source block converts the Simulink input signal into an equivalent current source. The generated current is driven by the input signal of the block. It can be initialized with a specific AC or DC current. If there is a need to start the simulation in steady state, the block input must be connected to a signal starting as a sinusoidal or DC waveform corresponding to the initial values.

figure 16: Controlled current source

SOLVER CONFIRGURATION:-



Each physical network represented by a connected Simscape block diagram requires solver settings information for simulation. The Solver Configuration block specifies the solver parameters that model needs before it can begin to simulate. Each topologically distinct Simscape block diagram requires exactly one Solver Configuration block to be connected to it.

figure 17: Solver configuration

LONGITUDINAL DRIVER :-

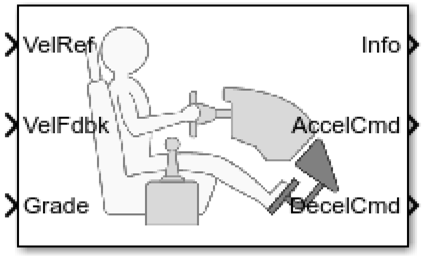


Figure 18: Longitudinal driver

The Longitudinal Driver block implements a longitudinal speed-tracking controller. Based on reference and feedback velocities, the block generates normalized acceleration and braking commands that can vary from 0 through 1. It can be used to model the dynamic response of a driver or to generate the commands necessary to track a longitudinal drive cycle.

SIMPLE GEAR :-

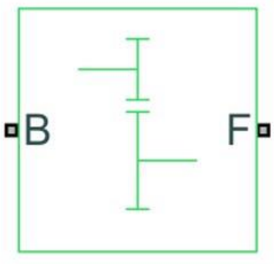


figure 19: Simple gear

The Simple Gear block represents a gearbox that constrains the connected driveline axes of the base gear, B, and the follower gear, F, to corotate with a fixed ratio that you specify. It can be choosen whether the follower axis rotates in the same or opposite direction as the base axis. If they rotate in the same direction, the angular velocity of the follower, ωF, and the angular velocity of the base, ωB, have the same sign. If they rotate in opposite directions, ωF and ωB have opposite signs. Backlash, faults, and thermal effects can be easily add or removed.

CONSTANT BLOCK :-

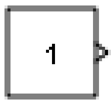


figure 20: Constant block

The Constant block generates a real or complex constant value signal. This block is used to provide a constant signal input. The block generates scalar, vector, or matrix output, depending on dimensionality of the Constant value parameter and setting of the Interpret vector parameters as 1-D parameter.The output of the block has the same dimensions and elements as the Constant value parameter.

SCOPE :-

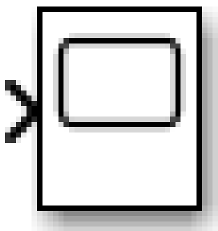


figure 21: Scope

Scope block is a visualization tool used to display and analyze simulation results in real time or post simulation. During simulation, the scope block continuously plots signals in real time as they are computed by simulation model, after simulation, the scope block retains the plotted signals, allowing users to review and analyze simulation results. The scope block can display multiple signals simultaneously which enables the comparison and correlation between different variables and system responses . so , the scope block serves as a valuable tool for visualizing , analyzing , and validating simulation results .

DISPLAY:-

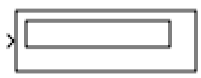


Figure 22: Display

The Display block connects to a signal in the model and displays its value during simulation. Its possible to edit the parameters of the Display block during simulation. The Display block can display complex, vector, and 2-D matrix signals.

BUS SELECTOR :-

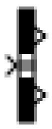


figure 23: Bus selector

The Bus Selector block extracts the elements that are selected by name from the input bus hierarchy. The block can output the selected elements separately or in a new virtual bus. When the block outputs the selected elements separately, each selected element corresponds to an output port. When the block outputs a new virtual bus, the block has one output port for the virtual bus that contains each selected element.

While multiple elements can have the same name in different locations in the bus hierarchy, each element has a unique fully qualified name that the Bus Selector block uses.

INTEGRATOR:-

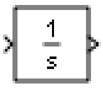


figure 24: Integrator

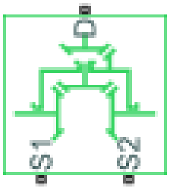
The Integrator block integrates an input signal with respect to time and provides the result as an output signal.

Simulink treats the Integrator block as a dynamic system with one state. The block dynamics are given by:

While these equations define an exact relationship in continuous time, Simulink uses numerical approximation methods to evaluate them with finite precision. Simulink can use several different numerical integration methods to compute the output of the block, each with advantages in particular applications.

The selected solver computes the output of the Integrator block at the current time step, using the current input value and the value of the state at the previous time step. To support this computational model, the Integrator block saves its output at the current time step for use by the solver to compute its output at the next time step. The block also provides the solver with an initial condition for use in computing the block's initial state at the beginning of a simulation. The default value of the initial condition is 0. Use the block parameter dialog box to specify another value for the initial condition or create an initial value input port on the block.

DIFFERENTIAL:-



The Differential block represents a gear mechanism that allows the driven shafts to spin at different speeds. Differentials are common in automobiles, where they enable the various wheels to spin at different speeds while cornering. Ports D, S1, and S2 represent the longitudinal driveshaft and the sun gear shafts of the differential, respectively. Any one of the shafts can drive the other two.

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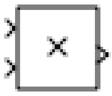
figure 25: Differential

PRODUCT:-



The Product block outputs the result of multiplying two inputs: two scalars, a scalar and a non scalar, or two non scalars that have the same dimensions.

figure 26: Product

EXPECTED RESULTS;-

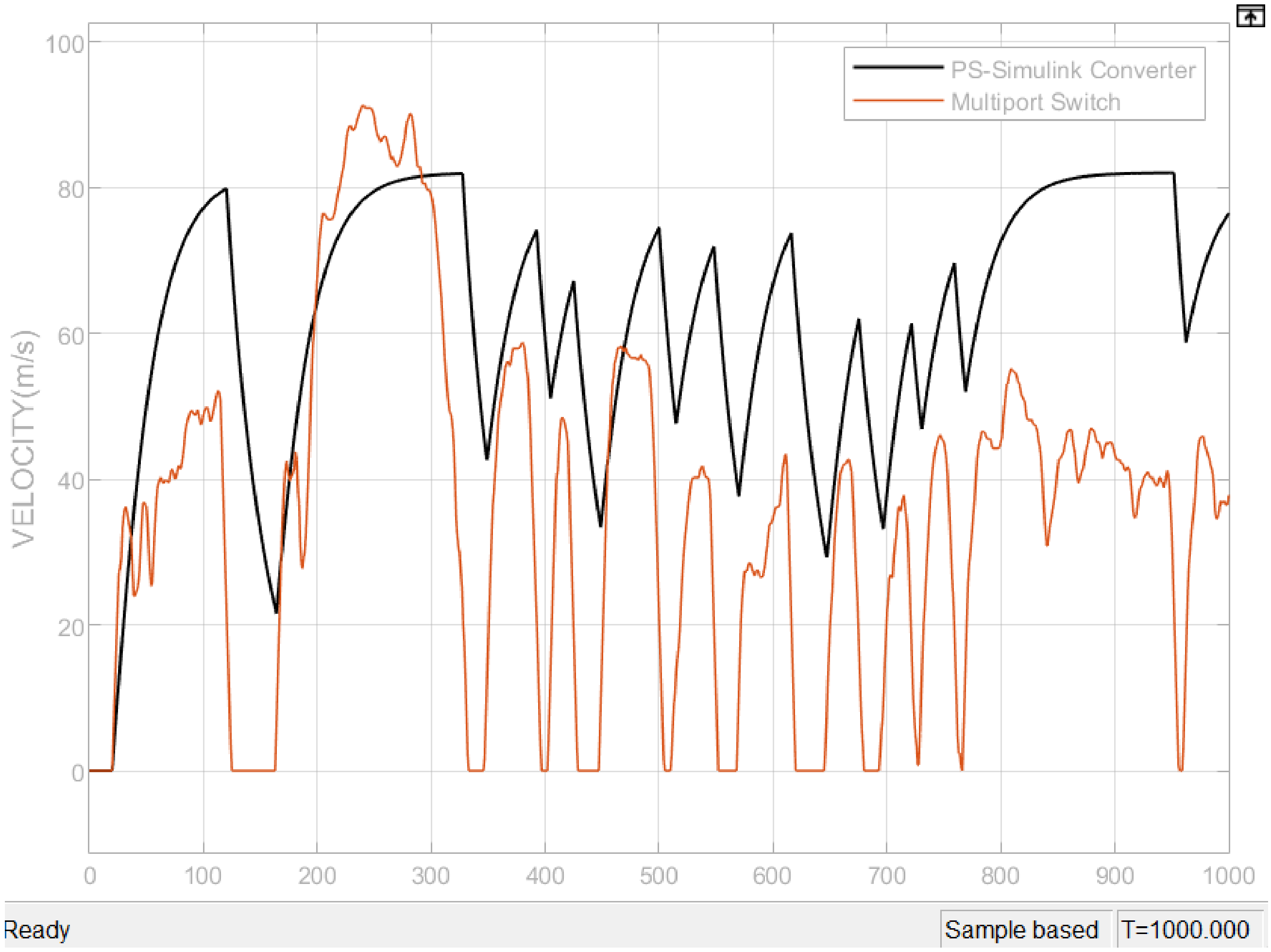


Figure 27: Comparison of drive cycle input with the actual output velocity of the vehicle for lithium ion battery

We compare the drive cycle input with actual output velocity to measure the vehicle's velocity in real time. This graph shows that actual output does not follow the drive cycle input closely which can be due to inefficiency and performance issues such as inadequate power delivery or mechanical issues affecting its ability to follow drive cycle.

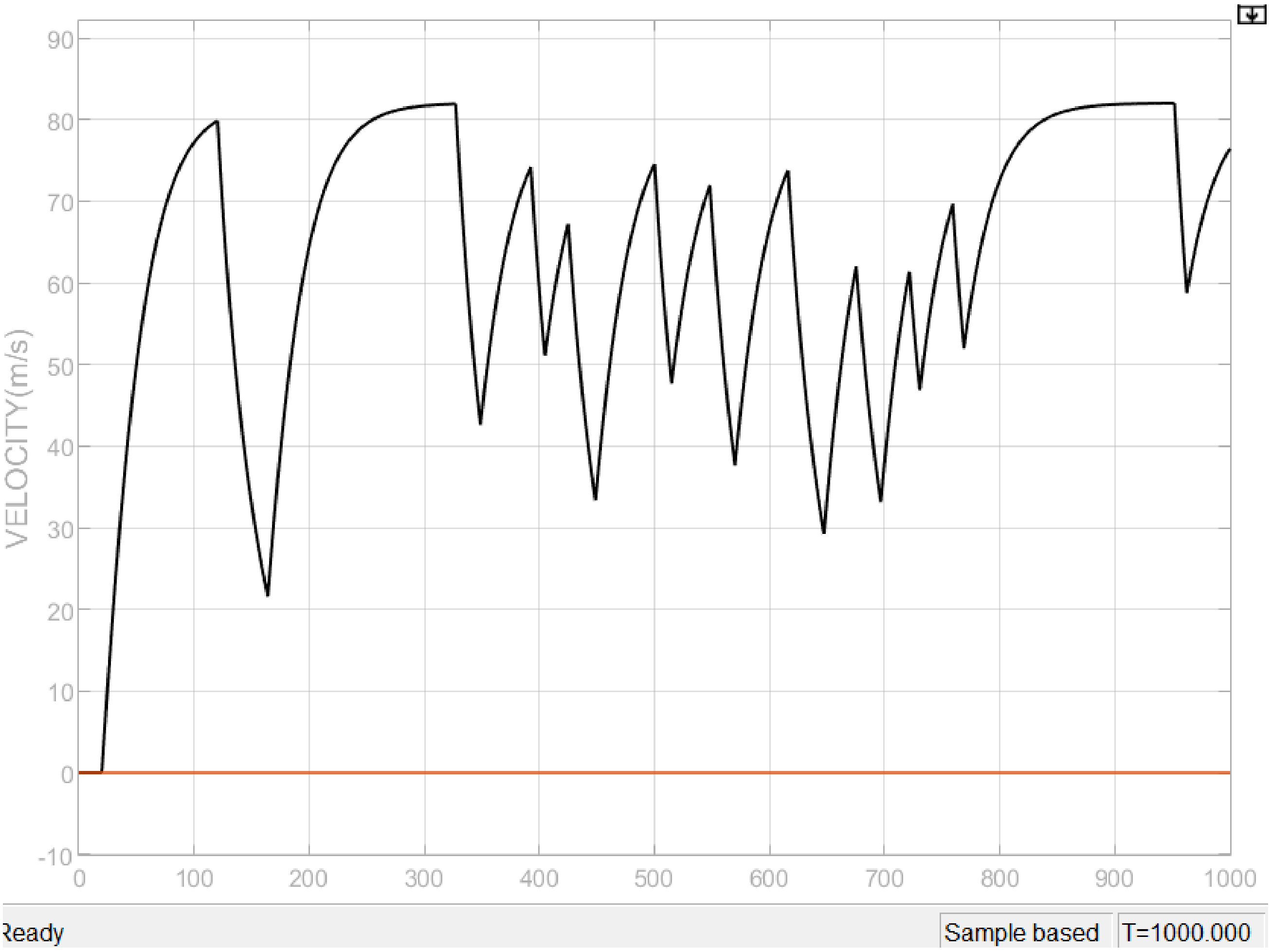


Figure 28:Output velocity of the vehicle for lithium ion battery

This graph shows constant spikes in output velocity as the time increases, this indicates that there are fluctuations in power delivery or this could also happen due inconsistent acceleration or breaking. These voltage spikes may effect vehicle performance and efficiency.

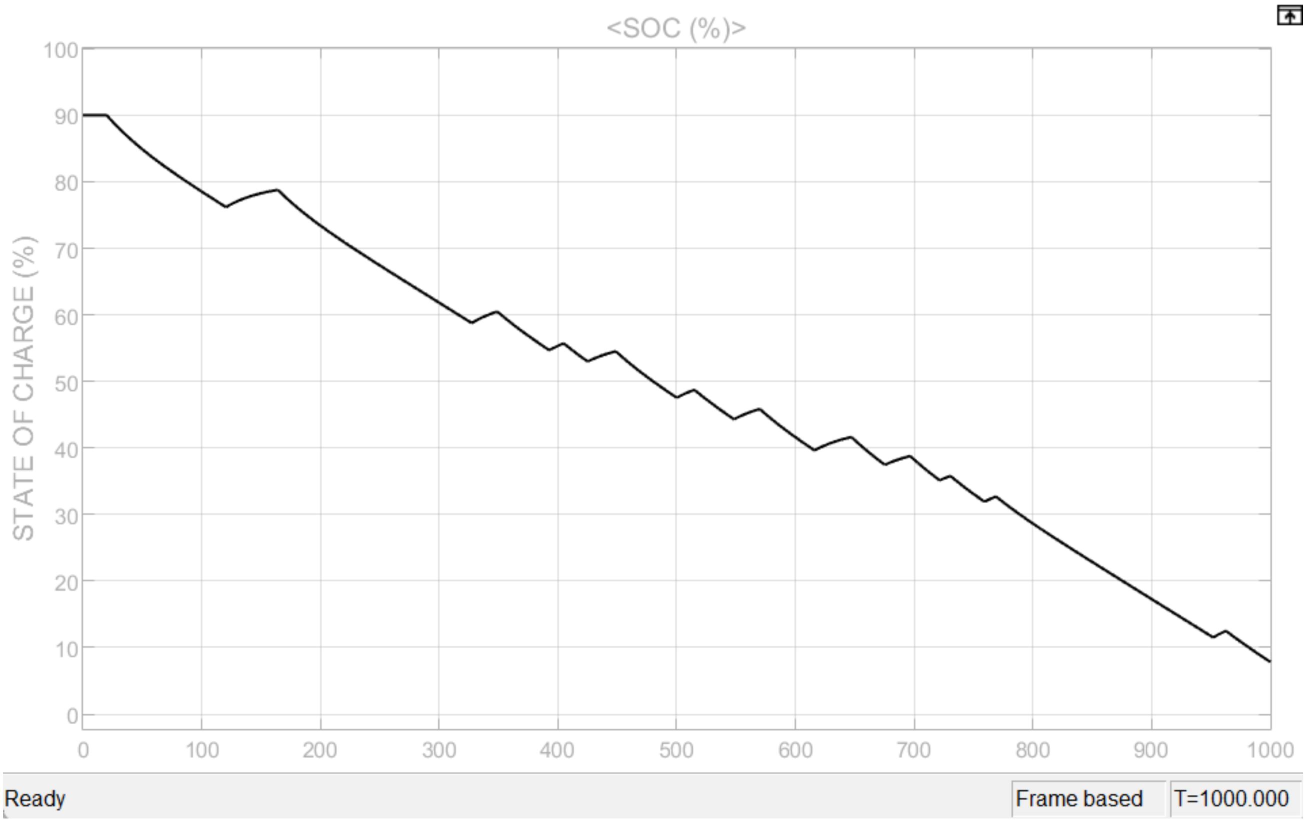


Figure 29: STATE OF CHARGE OF LITHIUM ION BATTERY

This graph is depicting that initial state of charge of the battery connected to electric vehicle is about 90% but as vehicle's run time keeps on increasing, the charge present in the battery keeps depleting. It shows how much charge is left in the battery at a particular time instant. SOC of the battery decides the range of vehicle as well.

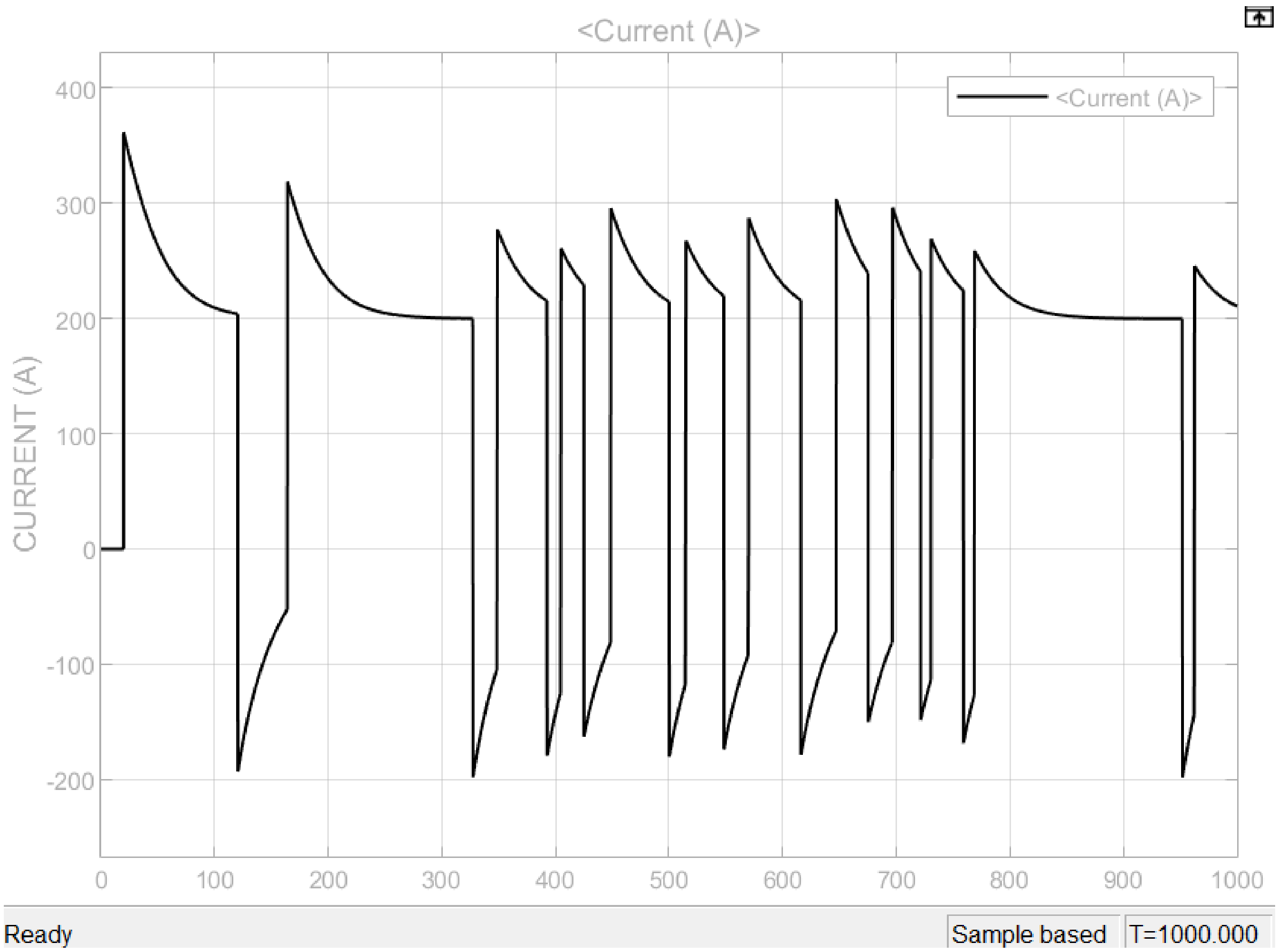


figure 30: Current profile of the lithium ion battery

The current profile of lithium ion battery here depicts how current flows into or out of the battery over time due to charging and discharging cycles. This graph depicts the rate at which energy is either being stored or released by the battery. This graph here shows that over the taken range of time, the battery current is continuously increasing and decreasing while at some time intervals this current use is also constant. Current drawn from the battery is affected by the vehicle load at that particular time interval.

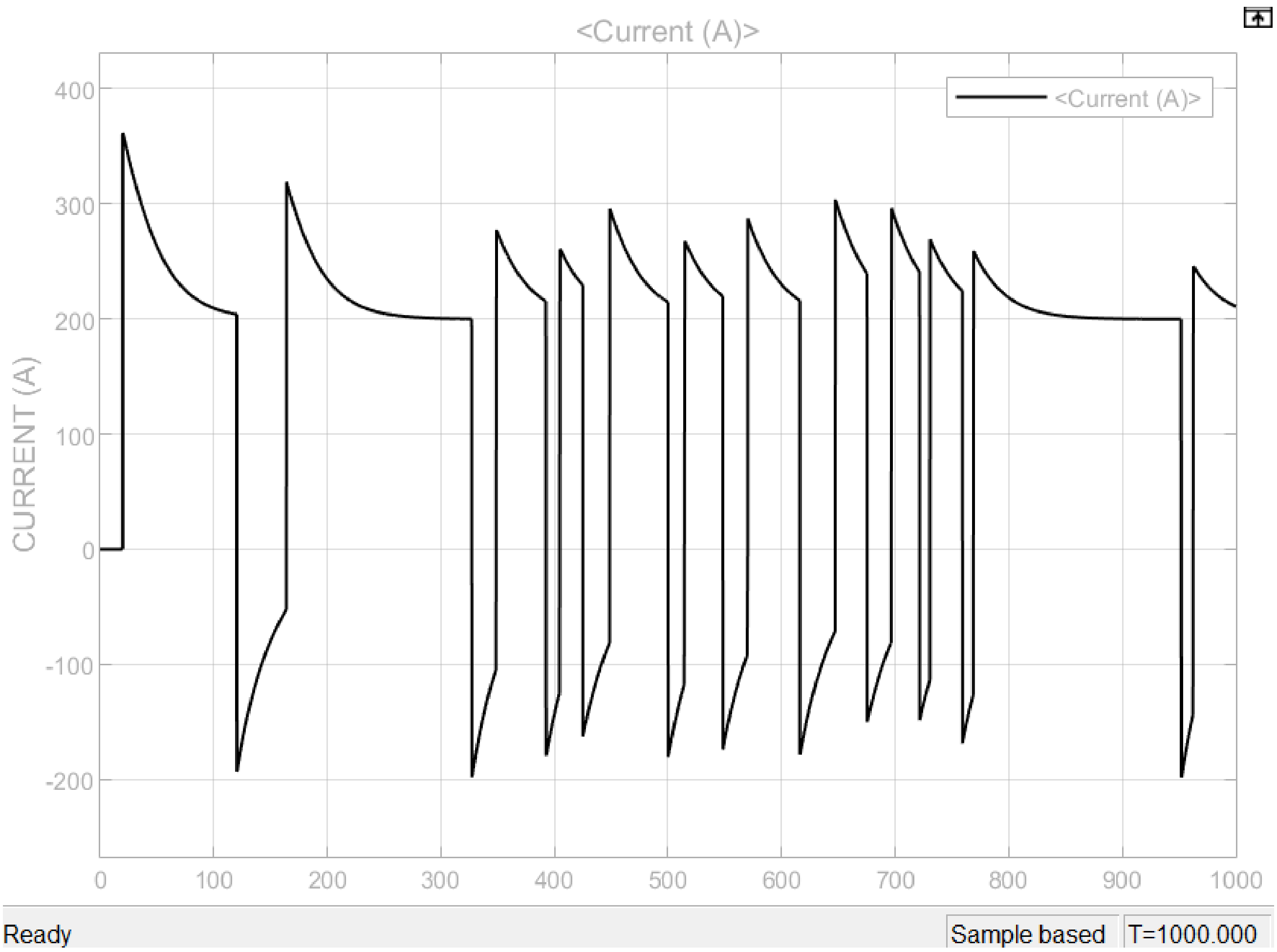


Figure 31: Current given to the dc motor by lithium ion battery

The current given to the DC motor of the electric vehicle is identical to the current profile of the battery as battery is providing it with this current. The current required by the motor is directly taken as output from the battery terminals.

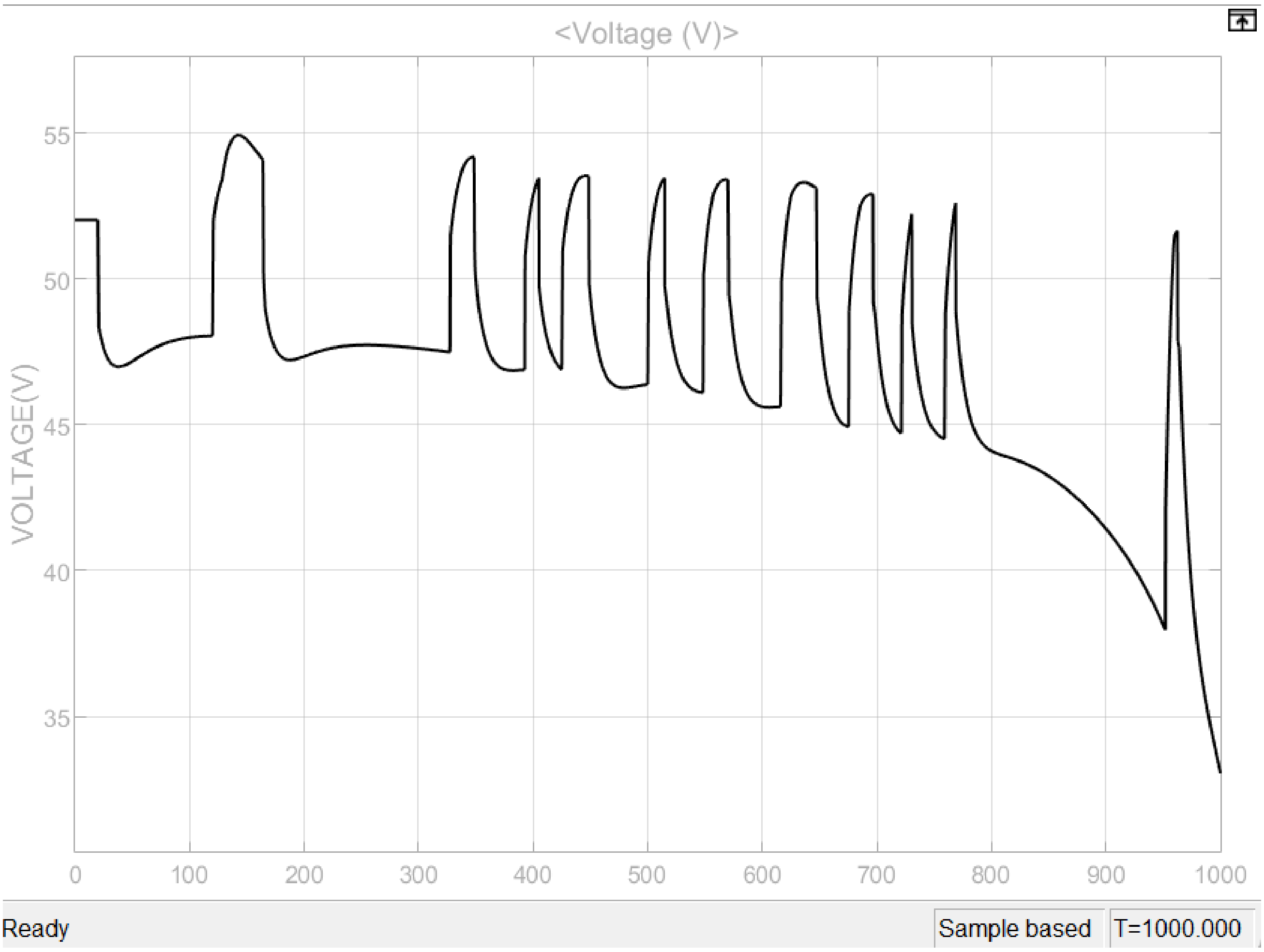


Figure 32: Voltage profile of the lithium ion battery

This graph depicts how the voltage changes over time. During charging , the voltage gradually increases as the battery takes in more energy reaching its maximum voltage when fully charged. Conversely, during discharge , the voltage decreases as the battery releases the stored energy to power the vehicle's electric motor. It shows battery's voltage at different states of charge and under various operating conditions.

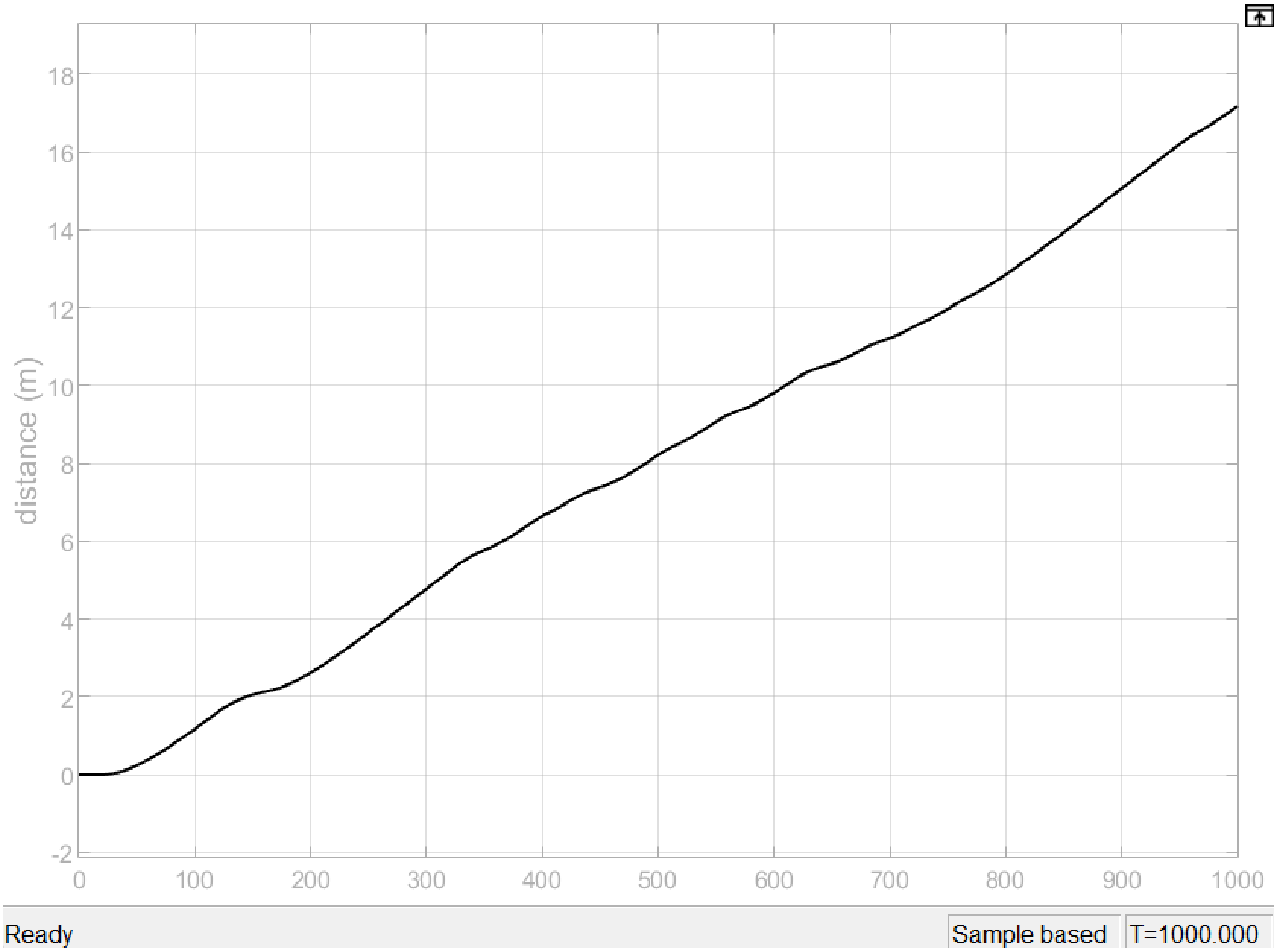


Figure 33: Distance travelled by the vehicle when it is powered by lithium ion battery

The graph of distance travelled by vehicle shows cumulative distance covered by the vehicle over specified time period. This graph also helps to provide a visual representation of how far the vehicle has travelled from it's starting point.

ADVANTAGES :-

Designing electric vehicles (EVs) using MATLAB offers several advantages due to its extensive capabilities for modeling, simulation, and analysis. Here's a detailed breakdown of the advantages:

1.Comprehensive System Modeling : MATLAB provides a versatile platform for modeling the entire EV system, including the battery, motor, power electronics, vehicle dynamics, and control systems.

2.Simulation and Validation : MATLAB enables engineers to simulate EV performance under various operating conditions, driving cycles, and environmental factors . Simulations can validate the design concept, optimize parameters, and predict system behavior before physical prototypes are built, saving time and resources .

3.Optimization : MATLAB's optimization tools allow engineers to optimize EV designs to meet specific performance, efficiency, and cost targets . Optimization algorithms can adjust parameters such as battery size, motor characteristics, control strategies, and vehicle aerodynamics to maximize overall system performance

3.Battery Management and Thermal Analysis : MATLAB facilitates the design and analysis of battery management systems (BMS) for monitoring and controlling battery operation . Engineers can model battery behavior, including state of charge (SoC), state of health (SOH), and temperature effects, to optimize battery performance and lifespan . Thermal analysis tools in MATLAB help predict and manage heat generation in EV components, such as batteries, motors, and power electronics, ensuring safe and efficient operation.

4.Motor Control and Power Electronics: MATLAB provides tools for designing, simulating, and implementing motor control algorithms and power electronics circuits .Engineers can develop and optimize control strategies for motor speed, torque, and efficiency, as well as for regenerative braking and traction control .

5.Vehicle Dynamics and Handling :MATLAB's vehicle dynamics modeling capabilities allow engineers to analyze and optimize vehicle handling, stability, and ride comfort .Engineers can simulate different suspension configurations, tire characteristics, and road conditions to improve overall vehicle performance and safety .

6.Real-Time Prototyping and Testing :MATLAB supports real-time prototyping and testing of EV control algorithms using hardware-in-the-loop (HIL) simulation .Engineers can interface MATLAB/Simulink models with physical hardware, such as motors, batteries, and sensors, to validate control algorithms in real-time and under realistic conditions .

7.Integration with Other Tools and Systems : MATLAB integrates seamlessly with other engineering tools and systems, allowing for interoperability and collaboration across multidisciplinary teams . Engineers can easily exchange data between MATLAB and other software tools for CAD, CFD, FEA, and system-level simulation .

8.Data Analysis and Visualization : MATLAB offers powerful data analysis and visualization tools that allow engineers to analyze simulation results, experimental data, and field test data . Engineers can visualize vehicle performance metrics, energy consumption, battery health, and other key parameters to gain insights and make informed design decisions .

9.Sensitivity Analysis and Robustness Testing : MATLAB enables engineers to perform sensitivity analysis and robustness testing to assess the impact of uncertainties and variations in design parameters

10. Model-Based Design (MBD):MATLAB supports model-based design (MBD) methodologies, allowing engineers to develop, simulate, and implement control algorithms and system models within a unified environment . MBD streamlines the design process, facilitates rapid prototyping, and ensures consistency between design models and implementation code.

11.Automatic Code Generation : MATLAB's automatic code generation capabilities enable the generation of production-ready code from simulation models . Engineers can automatically generate embedded software, controller firmware, and system integration code for implementation in real-time embedded systems .

12.Educational and Research Purposes :MATLAB is widely used in academic institutions and research laboratories for teaching, learning, and research in the field of electric vehicles. Students and researchers can access MATLAB's extensive library of tools, models, and resources to study EV technologies, develop new algorithms, and conduct advanced research.

13.Scalability and Flexibility :MATLAB's modular and scalable architecture allows for the development of EV designs ranging from simple components to complex integrated systems .Engineers can scale models and simulations as needed to accommodate different levels of detail and system complexity throughout the design process .

14.Community Support and Resources :MATLAB benefits from a large and active user community, providing access to forums, documentation, tutorials, and third-party add-ons. Engineers can leverage community resources to troubleshoot issues, share best practices, and stay up-to-date with the latest advancements in EV design and simulation.

These additional points highlight the diverse capabilities and advantages of using MATLAB for designing electric vehicles, making it a comprehensive and effective tool for engineers and researchers in the automotive industry.

DISADVANTAGES:-

While MATLAB offers numerous advantages for modeling complex systems, there are some potential disadvantages, particularly in terms of ease of modeling. Here are a few drawbacks that are encountered when using MATLAB for modeling:

1.Learning Curve :MATLAB has a steep learning curve, especially for beginners or those unfamiliar with programming .Understanding the syntax, data structures, and built-in functions can require significant time and effort .

2.Complexity of Models :Developing complex models in MATLAB may require advanced programming skills and mathematical knowledge .Managing large and intricate models can become challenging, leading to issues with code readability, organization, and maintenance

3.Performance Limitations :While MATLAB is powerful, it may not be the most efficient tool for computationally intensive simulations or large-scale modeling tasks .Certain operations or algorithms may run slower in MATLAB compared to compiled languages like C or Fortran .

4.Memory and Computational Resources :MATLAB's memory management and computational resources are finite, which can limit the size and complexity of models that can be simulated .Large datasets or high-resolution simulations may require substantial memory and processing power, leading to performance bottlenecks.

5.License Cost: MATLAB is a proprietary software with associated license costs, which may be prohibitive for some users or organizations, especially for large-scale deployments or academic use.

6. Limited Control Over Low-Level Operations: MATLAB abstracts away many low-level operations, which can limit users' control over memory allocation, parallel processing, and hardware optimization .For specific optimization tasks or performance-critical applications, users may need to resort to lower-level programming languages

7.Platform Dependency :MATLAB is primarily designed for Windows, with versions available for macOS and Linux as well. However, differences in platform implementations may lead to compatibility issues or platform-specific behavior .Limited Support for Real-Time Systems :While MATLAB supports real-time simulation and code generation, it may not be the best choice for real-time control systems or applications with strict timing requirements .

8.Vendor Lock-In :Developing models and simulations in MATLAB may result in vendor lock-in, making it difficult to migrate to alternative software platforms or integrate with other tools and systems. Despite these disadvantages, MATLAB remains a popular choice for modeling and simulation due to its rich set of features, extensive library of functions and toolboxes, and strong community support. It's essential to weigh these drawbacks against the benefits and consider alternative tools or approaches when appropriate.

9.Cost of Toolboxes :While MATLAB itself requires a license, additional toolboxes may be needed for specific modeling tasks or applications. The cost of acquiring multiple toolboxes can add up, especially for users with budget constraints or limited access to funding.

10. Compatibility Issues: MATLAB versions and toolboxes may not always be fully compatible with each other or with other software packages .Upgrading to newer versions of MATLAB or switching between versions can sometimes introduce compatibility issues or require modifications to existing code.

11.Lack of Industry Standards :MATLAB's proprietary nature and lack of industry-wide standards for modeling and simulation can pose challenges for interoperability and collaboration. Sharing models or collaborating with users of other modeling tools may require exporting models to common formats or developing custom interfaces.

12.Limited Support for Hardware-in-the-Loop (HIL) Simulation: While MATLAB supports hardware-in-the-loop (HIL) simulation, configuring and interfacing with external hardware may require additional tools or specialized knowledge Compatibility with specific hardware platforms or protocols may be limited, depending on the availability of drivers and support packages.

13.Version Control and Collaboration Challenges: Managing version control and collaborating on MATLAB models with multiple team members can be cumbersome, especially for larger projects. Without proper version control practices and tools, tracking changes, resolving conflicts, and maintaining code consistency can become difficult.

14.Performance Trade-offs: While MATLAB offers convenience and ease of use, there may be performance trade-offs compared to lower-level programming languages. Performance-critical applications or simulations requiring high computational efficiency may benefit from optimization in languages like C/C++ or Fortran.

These additional disadvantages highlight some of the challenges and limitations associated with using MATLAB for modeling and simulation, underscoring the importance of evaluating alternative tools and approaches based on specific project requirements and constraints.

CONCLUSION :-

In conclusion, the electric vehicle (EV) modeling project conducted in MATLAB has provided valuable insights into various aspects of EV performance, efficiency, and design. Through rigorous simulation and analysis, several significant findings have emerged:

1. Performance Evaluation: The MATLAB models allowed for comprehensive evaluation of EV performance metrics such as range, acceleration, and energy consumption under different driving conditions and scenarios.

2. Battery Management: The modeling effort shed light on the importance of effective battery management systems (BMS) in optimizing EV performance and extending battery life. .

3. Regenerative Braking: Simulation results highlighted the benefits of regenerative braking systems in capturing kinetic energy during deceleration and returning it to the battery, thereby improving energy efficiency and extending range.

Overall, the EV modeling project in MATLAB has contributed to the growing body of knowledge in the field of electric vehicles and sustainable transportation. The insights gained from this research can inform future developments in EV technology, policy-making, and infrastructure planning, ultimately contributing to a more sustainable and environmentally friendly transportation system.

As the technology continues to evolve and mature, further research and innovation will be essential to address remaining challenges and unlock the full potential of electric vehicles in achieving a cleaner, greener, and more sustainable future.

REFRENCES :-

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4. https://skill-lync.com/student-projects/final-project-design-of-an-electric-vehicle-40