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# Performance Analysis of Electric Vehicle using MATLAB/Simulink

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**Abstract:** *Electric vehicles (EVs) are likely to be an elective vitality mode of transportation for the long run because it features an incredible capacity to decrease the utilization of petroleum based and other tall CO2 transmitting transportations powers. In this introduction, the components of the BEVs framework like a battery, control converter, impetus framework, on board charger framework, powers on vehicle were examined and a demonstration of BEV on the MATLAB-Simulink was re-enacted. This introduction basically centres on modeling, re-enactment, and examination of a BEV and its components as expressed over. Electric vehicles are potentially to be adopted for green technology applications due to their batteries' high power density and high energy density. An accurate EV model in a simulation platform is very important to design an efficient battery-powered system. In this paper, an electrical vehicle model is developed in MATLAB/Simulink. The structure of the EV is explained in detail, and an EV model is presented. The developed EV model is validated from the experiment results. From the comparison, it reveals that the developed model is capable of predicting current-voltage performance accurately. Although the model has been developed for Simple Electric vehicles, it is expected that it can be applied for other types of EV. In MATLAB results we have verified the change Velocity of electric vehicles due to change in drive cycle*.

**Keywords:** Battery Electric Vehicle (BEV), Drive Cycle, MATLAB/SIMULINK, Modeling, State of Charge (SoC).

## I. INTRODUCTION

Electric and hybrid-electric vehicles stand out as key solutions to combat the pollution caused by fossil fuels and CO2 emissions [1]. These vehicles not only consume energy but also produce, store, and transport electricity, making them a promising alternative to traditional fuel engine vehicles [2]. In a recent presentation, MATLAB-Simulink was employed to craft the design of a Battery Electric Vehicle (BEV) along with its various components, seamlessly integrating the entire system [16]. The focus was on simulating the BEV model and its equations, ensuring a comprehensive understanding of its functioning. A crucial aspect of the BEV setup involves the transmission system, which links the electric vehicle components to the wheels. This system is meticulously designed to align with the electrical drive features and the specific requirements of the vehicle. The realm of Electric Vehicle (EV) simulation software is rich and diverse, offering tools like JANUS, V-ELPH, MARVEL, ADVISOR, MATLAB, LABVIEW [7], among others. These software solutions delve into the intricate electrical and dynamic behaviours of EVs, aiding in their efficient design and performance analysis [8]. Within this study, MATLAB-Simulink played a pivotal role in the design and simulation of BEV components. The paper not only discusses the simulation process but also delves into the verification of the BEV model and its relevant electrical system components. The analysis extends to scrutinizing all simulation results for a comprehensive understanding. Among the crucial BEV components discussed are the Transmission, Electric Motor, Battery Charge Controller, Driving Cycle, Driver Model, and Longitudinal Vehicle Dynamic Model. These elements collectively contribute to the efficient functioning of the electric vehicle. Battery management emerges as a critical consideration, necessitating the monitoring of parameters such as state-of-charge (SOC), current, and voltage. Proper handling of the battery is crucial to prevent issues such as overcharging or over-discharging. To aid circuit designers in managing energy consumption effectively, an accurate battery model becomes

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indispensable. MATLAB/Simulink emerges as a robust simulation tool for circuit and system designs, offering a range of user-friendly toolboxes and simulation blocks [9]. While the Sim Power Systems library includes a battery model based on the Shepard equation, it may not fully capture the nonlinear current-voltage performance of the battery. Hence, the paper proposes the development of a new battery model based on an equivalent circuit model within MATLAB/Simulink. This refined model promises more accurate simulation results, providing a closer reflection of the battery's actual behaviour. For instance, a Simulink model of a Li-ion battery has been crafted using Simulink blocks, incorporating average values of RC circuit parameters for model simplification. This approach ensures a more detailed and accurate representation of the battery's characteristics within the simulation [11]. In essence, the utilization of MATLAB-Simulink in the design, simulation, and analysis of Battery Electric Vehicles signifies a significant stride towards sustainable and efficient transportation solutions [16]. This integrated approach allows for a thorough understanding of EV dynamics, enabling advancements in design, performance, and energy management.

## II. MATLAB/SIMULINK SOFTWARE FOR EV SIMULATION

MATLAB is a programming platform designed specifically for engineers and scientists to analyse and design systems and products that transform our world. SIMULINK is a block diagram environment used to design systems with multi-domain models, simulate before moving to hardware, and deploy without writing code. It solves static, frequency domain, and time-varying magnetic and electric fields. And it provides a graphical editor, customized block libraries, and solvers for modeling and simulating the dynamic systems [8]. It is integrated with MATLAB, enabling you to incorporate MATLAB algorithms into models and export simulation results to MATLAB for further analysis. SIMULINK also offers specialized design interfaces for electrical, electronic and mechanical components & equipment. In this paper, the steps for the EV design process are highlighted. The SIMULINK also can be co-simulated with other tools like ANSYS, Motor Solve and many more [17].

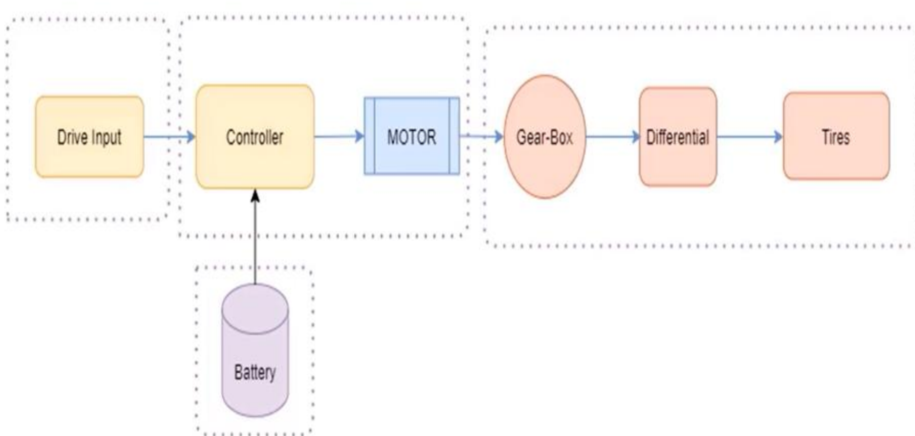


Fig. 1 Block diagram of EV Design

SIMULINK can be opened after running the MATLAB Software in the computer and by clicking the SIMULINK block seen in the MATLAB overview section as shown in Fig. 2. For the design of any setup, different desired blocks to be added together for the simulation. Similarly, for EV designing mainly six blocks are required as shown in Fig. 1, and to implement each block different components are required. So a library browser block is given in the SIMULINK where all the required components can be taken.


Fig. 2. MATLAB/SIMULINK Software Overview

## III. SPECIFICATIONS AND PARAMETERS USED IN THIS EV DESIGN

For the designing of any vehicle some reference data at standard operating conditions is required. In this study, TATA MOTORS [13] specification and other design parameters are considered for the simulation. All the specifications and parameters used in this EV design are taken from a specific model TATA NEXON EV [14]. The specifications of this vehicle are collected from the TATA Motors website and individual vehicle brochures files. All the desired parameters are filtered for this simulation study. All the data are taken from TATA MOTOR and TATA NEXON EV. The EV parameters like vehicle system parameter, parameter acting on the vehicle, and battery and motor parameters are listed below in Table 1, 2 and Table 3, respectively.

TABLE I. VEHICLE SYSTEM SPECIFICATIONS

| Parameters | Values | Units |
|---|---|---|
| Full Body Mass (M) | 1470 | kg |
| No. of wheels per axle (n) | 2 | - |
| Frontal Area (A) | 2.91 | $m^2$ |
| Gear Ratio (G) | 6 | - |
| Differential Gear Ratio | 1:1 | - |
| Wheel Size | R 16 215 / 60 LRR | - |
| Vehicle Gradeability | 35 | % |

TABLE II. PARAMETERS ACTING ON VEHICLE

| Parameters | Values | Units |
|---|---|---|
| Drag Coefficient | 0.15 | - |
| Coefficient Of Rolling Resistance | 0.01 | - |
| Gradient Angle (α) | 5 | ° |
| Air Density (ρ) | 1.225 | $kg/m^3$ |
| Acceleration Due to gravity | 9.81 | $m/s^2$ |
| Rolling Resistance Force (Frr) | 144.207 | N |
| Air Drag Force (Fdr) | 272.07 | N |
| Gradient Resistance Force (Fgr) | 1256.84 | N |
| Acceleration Force (Fac) | 4083.219 | N |
| Total Force | 5756.336 | N |

After having the necessary data it will be very easy for the designer to design a EV Model in SIMULINK platform. In TATA NEXON EV the type of battery used is Lithium Polymer or Lithium ion [11], motor type is three phase Permanent Magnet Synchronous Motor (PMSM) and the respective values are also mentioned in TABLE III.

TABLE III. BATTERY AND MOTOR SPECIFICATION

| Parameters | Values | Units |
|---|---|---|
| Battery Voltage | 320 | Volt |
| Battery Capacity | 30.2 | kWh |
| Motor Torque | 245 | Nm |
| Motor Power | 129 (95) | PS (kW) |
| Rated Speed Of Motor | 3800 | rpm |
| Acceleration 0 to 100 Km | 10 | Sec |
| Vehicle Range Per Charge | 312 | Km |

For a complete designing of an EV system, mainly six blocks are required as shown in Fig. 1.

## IV. RELATED WORK

**Transmission Demonstrate**

The Transmission show controls the vehicle's moving necessities all through an adapter. It shifts torque from engine show and braking drive into front and raises footing powers from driver demonstration. The two powers of the transmission yields are the inputs of the longitudinal vehicle energetically demonstrated.

**Electric Motor Model**

**Motor Speed Control**

The speed of the motor can be measured at different speed methods and instructions voltage. It is an input into the motor controller as shown in the equation below:

$$Wv = \alpha U + b$$

Where,

*Wv* = Motor speed regulation instruction voltage

U = characteristic curve approximates to a line

b = equation coefficient which also varies as the motor load changes.

**Regenerative Braking**

Regenerative braking tool captures the moving energy decrease of the vehicle and then converts it as electrical energy in order to feed it back into the battery source.

$$Wc = \frac{1}{n_c}\left(\frac{m_v^2}{2} + \text{mgh}\right)$$

Where,

Wc = Energy stored in the vehicle's power source

m = Total vehicle mass

V = Vehicle speed

H = Maximum height difference of the BEV

$n_c$ = energy efficiency of power source

**Battery Charge Controller Model**

This tool is responsible for the battery's longevity. Its importance is in employing an effective Battery Management System (BMS) in designing the BEV's electric system. BMS displays battery voltage, current, temperature, State of charge (SoC), measurement, and cell balancing. Based on the IRIZ battery, this model covers a simple battery pack. The state of charge (SOC) is obtained [4].

**Battery Pack**

It is composed of M modules connected in parallel; each module consists of N series-connected smaller elements called "cells".

$$SOD = \frac{1}{Q_T}\int_0^t \alpha\,[i(\tau)]\cdot\beta[T(\tau)]d_\tau$$

SOD = state of discharge, t = time, T = temperature, i = current.

**State of Charge**

In percentage, it expresses the remaining capacity of the battery that could be affected by the temperature, the discharge rate and the battery's life. As the equation below shows, the ratio between the residual charge available and the nominal capacity is the SoC.

$$SoC = \frac{Q(t)}{Q_{nom}}$$

Where,
Q (t) = ratio between the residual charge available,
Q nom = nominal capacity

**Driving Cycle**

It is the vehicle operation schedule that clarifies the terms of the speed and gear selection as a function of time during the simulation. Driving cycle NEDC Mode for small cars inside the city was selected in order to test fuel economy and vehicle performance of the small cars inside cities [2].

## V. METHODOLOGY

MATLAB-Simulink, known as MATLAB-Simulink, is used for designing the battery electric vehicle components and integrating the whole system [12]. Additionally, MATLAB-Simulink is utilized to simulate the battery electric vehicle and its corresponding equation for verification purposes [2,6].MATLAB, which is a technical computing language, combines programming, computation, and visualization in just one environment. It has been developing in order to solve engineering and scientific problems. It is currently being used in many different domains. MATLAB provides a powerful and rich graphic toolbox that allows the user to work in an easy and comfortable environment.

In the finely tuned symphony of modern vehicle operation, the pivotal role of driver input initiates a complex dance among controllers, motors, and gear systems [17]. A driver's touch on the accelerator sends signals to the electronic control unit (ECU), acting as the maestro guiding the orchestra of mechanical components. Picture the motor as the pulsing heart, responding to the ECU's directives—be it through fuel injections in traditional engines or the quiet hum of electric motors in EVs. This energy then flows through the gearbox, a marvel of engineering that translates raw power into usable torque, adjusting speed and performance based on the driver's commands. Meanwhile, the humble yet vital differential ensures smooth turns and stability, redistributing power as the vehicle navigates corners. Each element, from the driver's intent to the gearbox's precision, forms an intricate tapestry of motion. Together, they create a symphony of engineering prowess, where every gear change and wheel turn is part of a grand performance, showcasing human ingenuity and the relentless pursuit of automotive excellence.

**MATLAB Simulink Model**

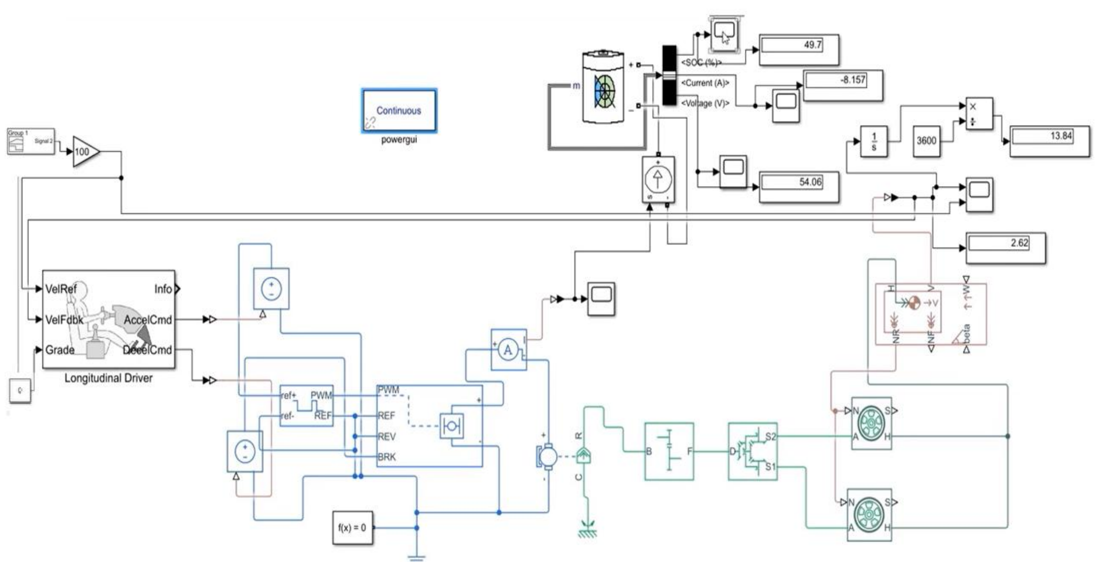


Fig. 3. Final EV Model Designed in Simulink

In developing a simulation for a Battery Electric Vehicle (BEV), six essential components were carefully chosen to create an accurate model. These components include the transmission model, electric motor model, battery charge

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controller model, driving cycle, driver model, and the longitudinal vehicle dynamics model. Each element plays a crucial role in the simulation, representing key aspects of the BEV's behaviour. From how power is transmitted through the transmission and electric motor to how the battery charge is controlled, these models work together to mimic real-world driving scenarios. By integrating these components, the simulation aims to provide insights into the performance and efficiency of the BEV in various driving conditions, aiding in the development of future electric vehicles [18].

## VI. STEPS FOR SIMULATION AND RESULTS ANALYSIS

After designing the Vehicle blocks, result analysis is required, for that a Powergui block from the library as a Continuous Solver is added as shown in Fig. 3.

Here step by step approaches for simulation of all the blocs are discussed.

A. STEP 1: Drive Source Setup After opening and running the MATLAB/SIMULINK Software an untitled SIMULINK file will pop-up. The first block of the EV system is the drive cycle. So the design process should be started from the drive Source design, for that a drive cycle Block from Library Browser to be selected. For the drive cycle source setup, drive cycle is the basic required block, after double clicking on that different available drive cycles will be open, or by installing the drive cycle if not installed previously. A new drive cycle source can also be added to the library by using different types of source format like excel file, slider, data sheet, etc as drive cycle source. In this paper, three different types of drive cycle sources are taken. The first drive cycle source is already available in the SIMULINK library, the second source uses an excel data sheet and the third one is a manual type of drive cycle source where a slider is given inside it as an accelerator. A multiport switch is used to deliver a single Drive Cycle data at a time. For that a constant block is connected to change the input source by changing the constant form 1-3 as three drive cycle sources connected to the multi-port switch as shown in Fig. 3.

B. STEP 2: Driver Control Design After design of the drive cycle source [10], a driver control block to be designed by selecting the longitudinal driver. The longitudinal driver block is a proportional-integral (PI) type driver controller. There are three input and three output ports. Here VelRef port for drive cycle as input and VelFdbk port for feedback as PI controller type is used. As grade is not required for now so it is marked as 0 by adding a constant block. The acceleration command signal is given to a Controlled voltage source which delivers the signal to the Controlled PWM Voltage block which is connected to a H-Bridge. So that depending on the acceleration given by the driver the Controlled PWM Voltage will give the signal to the H-bridge converter to run the motor according to that and the vehicle will move. Similarly, the deceleration command is also given to the H-bridge converter so that the motor can slow down or stop and the motor will act like a generator where regenerative braking will happen. All the references are electrically grounded along with a solver configuration which defines solver settings to use for simulation. The complete driver control design process is shown in Fig. 3. The PWM frequency used in the controlled PWM voltage is 4000 Hz, and input voltage 0V for 0% duty cycle and 1V for 100% duty cycle in the input scaling, where output voltage amplitude is taken as 5V.

C. STEP 3: Motor Controller Design Electric Vehicle motor is the main device for vehicle movement. So motor control is very important for proper vehicle running and regenerative braking in an efficient way. Here the H-bridge converter is taken from SIMULINK library to control the motor and for regeneration of electric power during deceleration. The PWM input port is connected with the output PWM of the controlled PWM voltage block, the brake input port is connected with the signal coming from the driver controller and the references are electrically grounded. Its positive and negative output port will be connected with the motor.

D. STEP 4: Battery Setup Design After the motor controller design, the battery setup is to be designed. Here a 320V Lithium-Ion battery is considered [11]. The rated capacity of 95kWh, initial State of Charge (SoC) as 100% and the battery response time is 0.1second. Here a current sensor is connected with the H-Bridge and then with the battery. A controlled current source block is connected with the battery so that it can be used as both source and storage during regenerative braking. A bus selector is connected with the battery to keep the record of battery SoC during charging and discharging. For the observation of real time data, the required display & scope is connected with the bus selector block. The battery setup with the complete battery management system (BMS) is shown in Fig. 3. .

E. STEP 5: Motor Design & Parameters Setting In the TATA NEXON EV a 3-phase PMSM Motor is taken [13]. But here we will be using a Permanent Magnet DC Motor of the same rating. The positive and negative terminal of the

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motor is connected with the H-Bridge, the stator is connected with a mechanical rotational reference where the rotor of the motor is connected with the gear shaft of the vehicle body. In between a torque sensor is used to measure the torque produced by the motor. The complete Motor design setup is shown in Fig. 3.

F. STEP 6: Vehicle Body Design Vehicle Body is the very basic, main and important part for a vehicle. A vehicle body consists of lots of different parts but the main are Vehicle Frame, Chassis, and Wheel & Power transmission parts. Here first we will select Vehicle Body from Simulink Library or by searching Vehicle Body on the workspace as shown in Fig. 3. Then we will set all the required parameters in the Vehicle body as shown in Fig. 3.

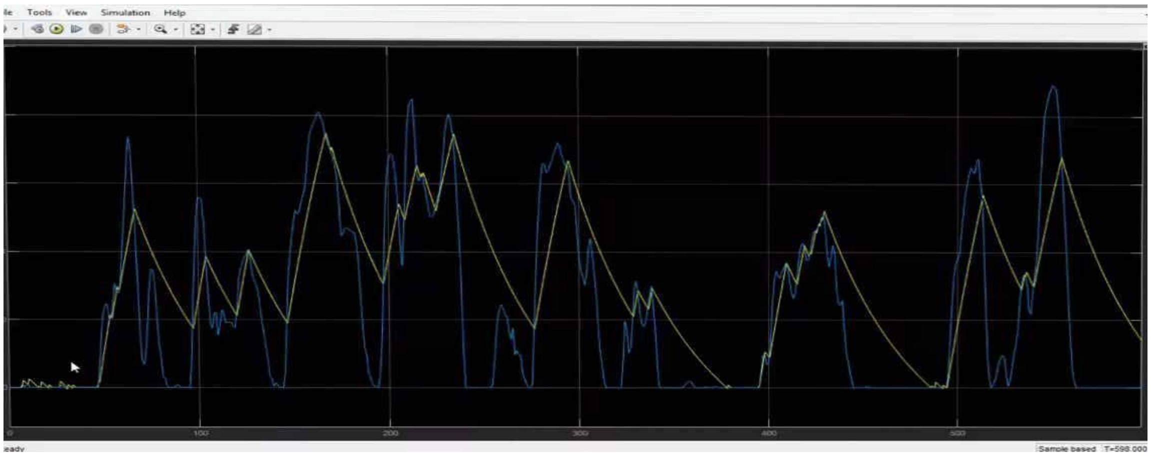


Fig. 4. Reference Speed with Actual Speed of Electric vehicle

This graph occurs due to the predictive control type of the longitudinal driver parameter. The fig. 4 represents the actual and reference speed of the electric vehicle where the yellow line is the actual speed and blue line is the reference line.

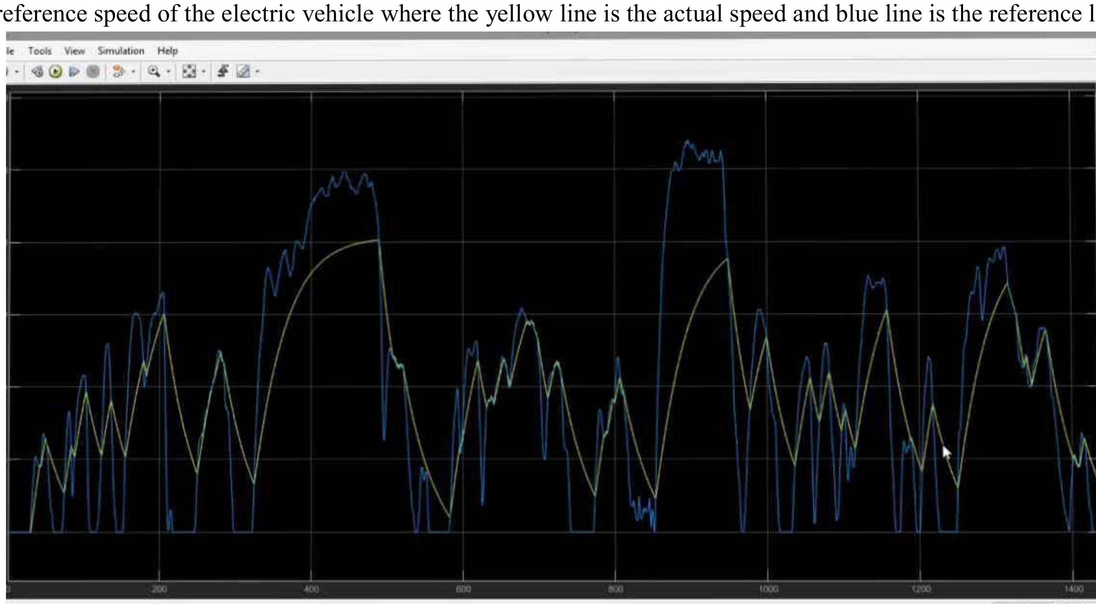


Fig. 5. Reference Speed with Actual Speed of Electric vehicle after changing driver setting

When we change the driver setting in the MATLAB the actual speed changes as shown in Fig. 5 and we get the output. It is also possible to change the other parameters in the MATLAB/Simulink by which we can verify the results in the final output section of the result.

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Fig. 6. State of charge variation due to Regenerative braking.

Due to the acceleration and some increment occurs in the graph due to braking action being applied. The SOC varies as per the regenerative braking whenever it is getting applied to the electric motor. Fig. 6 shows the state of charge variation due to regenerative braking.

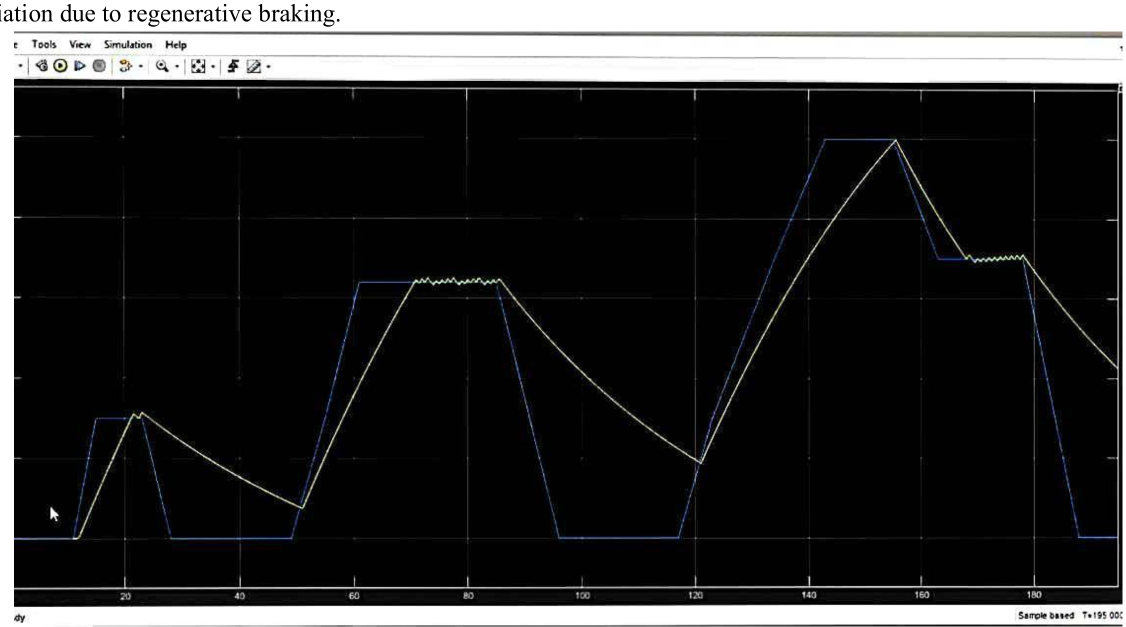


Fig. 7. Velocity Graph

When we change the drive cycle from the input side the velocity changes accordingly. For this we have to Change the drive cycle source in MATLAB input.

Here in MATLAB we can change various parameters like motor HP, Driver setting, Controller type and verify the results. This occurs due to fixed step of solver.

## VII. CONCLUSION

In this paper, a complete step-by-step approach for designing an EV using MATLAB/SIMULINK has been discussed. The performance of the designed model is observed to be quite efficient around 95% efficiency along with the given drive cycle. Here, the detailed parameters for simulating the model with the components specification have been highlighted. All the parameters of the complete EV designing, simulation parameters, and result analysis part in SIMULINK have been presented. The step-by-step approaches will help researchers, students, and beginners in this field for the EV designing and performance analysis using MATLAB/SIMULINK Software.In this study, BEV and its components have been simulated in order to investigate the energy flow,performance and efficiency. Good results for different parameters of velocity and percentage of state of charge were shown by using MATLAB-Simulink. An accurate MATLAB/Simulink Electric Vehicle model has been proposed to characterize the dynamic characteristics of the BEV. The structures of each subsystem of the proposed model have been explained in detail. A BEV model battery has been developed and the accuracy of the proposed model has been proven with experiment results. It is expected that the model is applicable for other Electric Vehicles, such as Hybrid Electric Vehicle (HEV), Mild Hybrid Electric Vehicles (MHEV),Plug-in Hybrid Electric Vehicles (PHEV), Range-extended Electric Vehicle (RE-EV), Hydrogen vehicle (FCEV). Circuit designers can easily build up their EV model since it does not involve any complex computation. This simple yet accurate EV model in simulation platform will eventually accelerate the development of Electric Vehicle systems in green technology applications. We can conclude that the actual speed is trying to follow the reference speed

## REFERENCES


**[1].** Mohamed YAICH, Mohamed Radhouan HACHICHA, Moez GHARIANI, "Modeling and Simulation of Electric and Hybrid Vehicles for Recreational Vehicle" (16th international conference on Sciences and Techniques of Automatic control & computer engineering - STA'2015).

**[2].** Sunil Magan More, Dr.Brajesh Mohan Gupta, "Advancement In Electric Vehicle Battery", e-ISSN: 2582-5208, International Research Journal of Modernization in Engineering Technology and Science, ( Peer-Reviewed, Open Access, Fully Refereed International Journal ),Volume:06/Issue:07/July-2024 Impact Factor- 7.868 www.irjmets.com

**[3].** A.A. Abulifa, R.K. Raja Ahmad, A Che Soh, M.A.M. Radzi, M.K. Hassan, "Modelling and Simulation of Battery Electric Vehicle by Using MATLAB-Simulink" (2017 IEEE 15th Student Conference on Research and Development).

**[4].** Sunil Magan More, Dr.Brajesh Mohan Gupta,"Battery Thermal Management System for Lithium-ion Cells by using thermoelectric module" International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 10 Issue: 03 | Mar 2024 www.irjet.net p-ISSN: 2395-0072.

**[5].** Jian Zhou1 (Corresponding), Xiangming Shen2 and Dong Liu3, "Modeling and Simulation for Electric Vehicle Powertrain Controls" (ITEC Asia-Pacific 2014).

**[6].** FazelMohammadi, Gholam-Abbas Nazri" Modeling, Simulation, and Analysis of Hybrid Electric Vehicle Using MATLAB/Simulink" (5th International Conference).

**[7].** Saiful A. Zulkifli* ° and Muhd. AnisrudienMohd. Dali*, "Development of Vehicle Powertrain Simulation Module by Interfacing Matlab-ADVISOR to LabVIEW"( 2017 IEEE Conference).

**[8].** AdamantiosBampoulas, Andreas Giannakis, Sofia Tsaklidou,AthanasiosKarlis, "Modeling, Simulation and Performance Evaluation of a Low-Speed Battery Electric Vehicle"( 2016 Eleventh International Conference).

**[9].** NetraLokhande, AnirudhdaDeore, Jaya Dinani, "Range Estimation of Electric Vehicle using MATLAB"( 2021 6th International Conference).

**[10].** AimanNouh, MouhcineChami, Faisal A. Mohamed, "Modeling and Simulation for Powertrain Design and Control of Unconventional Vehicles"(2015 6th International Renewable Energy Congress).

**[11].** Low Wen Yao, Aziz, J. A., Pui Yee Kong, N. R. N. Idris, "Modeling of Lithium-Ion Battery Using MATLAB/Simulink".

**[12].** A.A. Abulifa, R.K. Raja Ahmad, A Che Soh, M.A.M. Radzi, M.K. Hassan, "Modelling and Simulation of Battery Electric Vehicle by Using MATLAB-Simulink"( 2017 IEEE 15th Student Conference on Research and Development).

**[13].** TATA NEXON EV - Technical Specifications & Features "https://nexonev.tatamotors.com/wp-content/themes/tatanexon/images/Nexon-EV-MAX-Brochure.pdf".

**[14].** Specifications & Features of Tata Nexon EV & Dark Edition "https://nexonev.tatamotors.com/features/"

**[15].** F. Mohammadi, G. -A. Nazri and M. Saif, "Modeling, Simulation, and Analysis of Hybrid Electric Vehicle Using MATLAB/Simulink," 2019 International Conference on Power Generation Systems and Renewable Energy Technologies (PGSRET), 2019, pp. 1-5.

**[16].** Y. Inoue, T. Kosaka, H. Matsumori and N. Matsui, "Modeling and Simulation of Battery-powered Electric Vehicle on MATLAB/Simulink," 2021 24th International Conference on Electrical Machines and Systems (ICEMS), 2021, pp. 694-698.

**[17].** N. Hashemnia and B. Asaei, "Comparative study of using different electric motors in the electric vehicles," 2008 18th International Conference on Electrical Machines, 2008, pp. 1-5, doi: 10.1109/ICELMACH.2008.4800157.

**[18].** Z. Cao, A. Mahmoudi, S. Kahourzade and W. L. Soong, "An Overview of Electric Motors for Electric Vehicles," 2021 31st Australasian Universities Power Engineering Conference (AUPEC), 2021, pp. 1-6, doi: 10.1109/AUPEC52110.2021.9597739.