Electric Vehicle Modeling & Simulation Using MATLAB SIMULINK

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Abstract:
In this design, we use MATLAB SIMULINK tool blocks to create an electric car model. Vehicles using IC engines perform well and last longer. However, as a result of low energy efficiency and pollution-causing emigrations, interest in electric vehicles is growing. Electric vehicles have a limited range and cannot go at high speeds. Long-range vehicles are becoming more common as battery and electric motor technology improves. As a result, by selecting the motor and battery based on the region and driving cycle, the performance of these cars may be improved. In this study, the dynamics model of an electric car was created using MATLAB SIMULINK.
Keywords: *Electric vehicle, MATLAB SIMULINK, Simulation Drive Cycle.*

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1. **Introduction**: Energy conservation is one of the most pressing issues confronting the world's climate. The global energy climate is also under threat one accurately predicts the future of energy; We believe that transportation will play an important role in saving energy in the future EVs are currently products of technological innovation that have contributed to making our lives easier and safer. Electric vehicles not only consume energy but also produce, store and transport it. They are therefore an excellent fuel vehicle option. The recent development of hybrid and electric vehicles is closely related to the need for highly efficient machines capable of meeting the latest emissions regulations. In the automotive industry, electric propulsion is now a mature technology that is already available on the market and capable of meeting pollutant emission regulations based on the most recent testing process. In recent days, Electric vehicles represent the most viable alternative to the IC engines. Batteries may behave differently depending on operating temperature, actual capacity, and aging conditions.

2. The MATLAB/Simulink program has proven to be a useful modelling platform, capable of simulating full EV powertrains at various degrees of realism and detail. The software includes a number of models that may be used to simulate both pure battery electric and hybrid electric vehicles in various configurations and types [12–15]. Many add-ons already used in the vehicle

model, including as the Super system and SimDriveline [15], Advisor [13], Sims cape, Powertrain Block set, and others, are supported by the MATLAB/Simulink platform, as well as the physical modelling approach. Simulink also includes hardware testing and implementation code creation, as well as testing and analysis frameworks for test case management and reporting. There have been various studies of MATLAB/Simulink models published in the literature. However, no approaches for verifying these models in a real-world research setting have been developed.

3. Block Diagram of Proposed Model: It consists the following main blocks, 1.)Vehicle body, 2.)DC Motor,3.)Power converter, 4.)Battery,5.)Drivecontroller,6.)Drive cycle

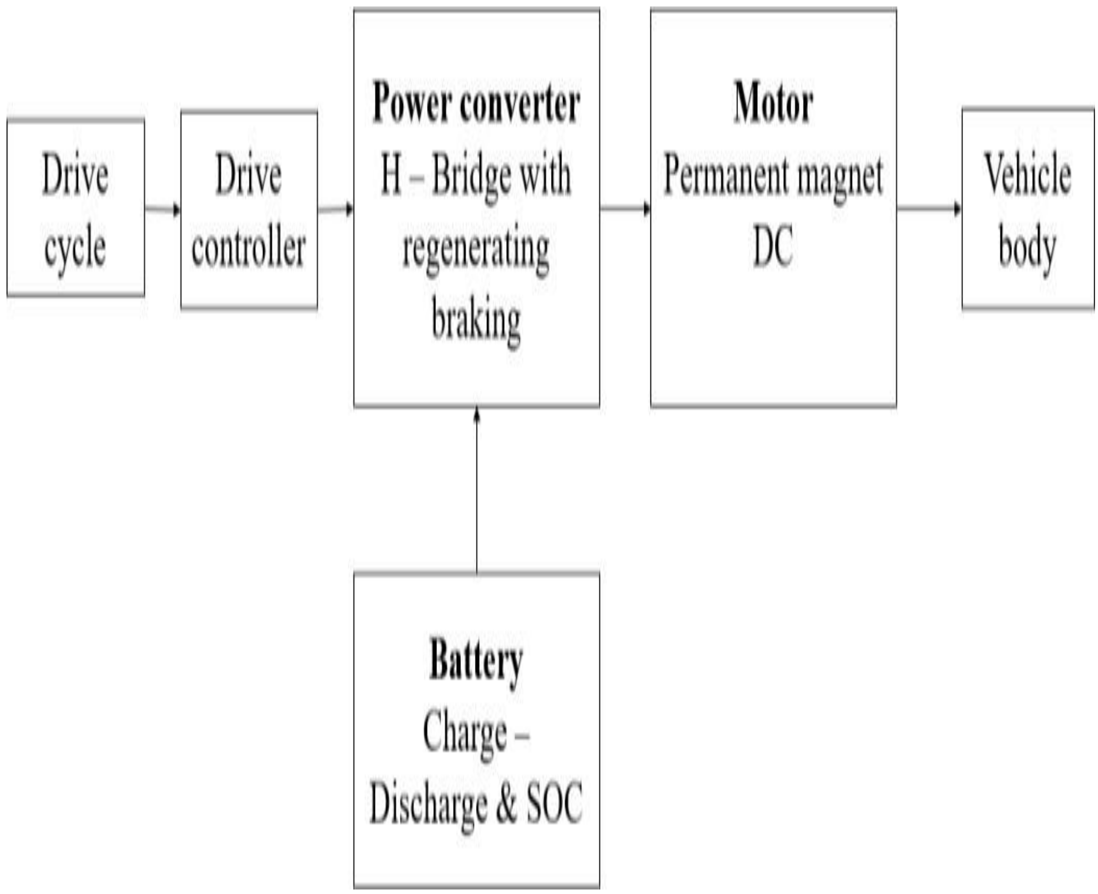

Figure1: Block diagram of the Proposed model

4.Tool Blocks Used:

A. Vehicle Body: The two-axle body travelling in a straight line is represented by the Body Block. Two front wheels and one rear wheel, for example. Two front wheels and one rear wheel, for example. Body mass, aerodynamic drag, road inclination, and weight distribution between the axles owing to acceleration and the road surface are all taken into account in this block. Pitch and suspension dynamics are two options. The vehicle's axes are parallel and create a plane.

This plane contains the longitudinal direction, x, which is perpendicular to the axis. When going down an incline, the normal z is always perpendicular to the longitudinal plane of the axis and never parallel to gravity.

- The vehicle motion is a result of the net effect of all the forces and torques acting on it.
- The weight *mg* of the vehicle acts through its center of gravity(CG).

$$m\dot{V}_x = F_x - F_d - mg * \sin\beta$$

$$F_x = n(F_{xf} + F_{xr})$$

$$F_d = ½ * C_d \rho A (V_x + V_w)^2 \cdot sgn(V_x + V_w)$$

- The normal force on each front and rear wheel.

$$F_{zf} = \frac{-h(F_d + mg\sin\beta + m\dot{V}_x) + b \cdot mg\cos\beta}{n(a+b)}$$

$$F_{zr} = \frac{+h(F_d + mg\sin\beta + m\dot{V}_x) + a \cdot mg\cos\beta}{n(a+b)}$$

- The wheel's normal forces satisfy

$$F_{zf} + F_{zr} = \frac{mg\cos\beta}{n}$$

- Pitch accelerationdependsonthreetorquecomponentsandtheinertiaofthevehicle

$$a = \frac{(f \cdot h) + (F_{zF} a) - (F_{zr} b)}{J}$$

Where:
a is the pitch acceleration.
F is the longitudinal force.
h is the height of the center of gravity when measured parallel to the *z*-axis. *J* is inertia.

B. Tire: The tire's longitudinal movement is the same as when it is rolling along the road. It is a structural element based on the Tire Road Interactive block (Magic Formula). To improve the authenticity of the tyre model, you can select tyre compliance, inertia, and rolling resistance. These attributes, on the other hand, contribute to the tyre model's complexity and can cause the simulation to run slowly. Consider eliminating tyre compliance and inertia if you're running the model in real time or prepping for hardware in the loop (HIL) simulation.

C. DC Motor: The DC Motor block uses the following equivalent circuit model to represent the tourque and electrical characteristics of a DC motor. The resistor R is equivalent to the resistance specified in the parameters of Armature resistance. The inductor L is equivalent to the inductance specified in the parameters of Armature inductance.

- The motor is having permanent magnets that cause the armature to experience the following back emf vb.

$$v_b = k_v \omega$$

- whereas k_v denotes the Back-emf constant and angular velocity motor produces the following torque, which is proportional to the motor current I.

$$T_E = k_t$$

Where k_t is the Torque constant

- Equating these two terms gives

$T_E\ \omega = v_b i k_t I \omega = k_v \omega i$

$k_v = k_t$

- TheblockmodelsmotorinertiaJanddampingλforallvaluesoftheModelparameterization parameter. The resulting torque across the block is

$$T = \frac{k_t}{R}(V - k_\omega) - J\dot{\omega} - \lambda\omega$$

D. Power Controller: The tool blocks in a DC motor power controller are (a) H-Bridge and (b) Controlled PWM Voltage.

E. (a).H-Bridge: This block has simulation mode options as given: 1) PWM, 2) Mean The H-Bridge block's output is a controlled voltage determined by the input signal at the PWM port. When the input signal exceeds the Enable threshold voltage value, the H-Bridge block output is activated and has a value equal to the output voltage value. The averaged model is the other mode. In this mode smoothed and unsmoothed load current characteristics are available. The Smoothed option assumes that the current is nearly continuous due to load inductance. In this case, the H-Bridge block output is

$$\frac{V_O V_{PWM}}{A_{PWM}} - I_{OUT} R_{ON}$$

where:

V_O is the value of the output voltage amplitude parameter.

V_{PWM} is the value of the voltage at the PWM port.

A_{PWM} is the value of the PWM signal amplitude parameter.

I_{OUT} is the value of the output current.

R_{ON} is the Bridge on the resistance parameter.

(b).Controlled PWM Voltage: The Controlled PWM Voltage block represents a pulse-width modulation (PWM). In the Modeling option parameter, choose between electrical and physical signal input ports. Using the reference voltage across its ref and ref gates, the block calculates the duty cycle. The duty cycle value can be set directly via the physical input signal port. The appropriate duty cycle is given when modelling electrical input ports.

$$100 * \frac{V_{ref} - V_{min}}{V_{max} - V_{min}} \text{ percent}$$

Where as:

V_{ref}isthereferencevoltageacross theref+andref-ports.

V_{min} is the minimum reference voltage.

V_{max} is the maximum reference voltage.

F. Drive Cycle: A standard or user-specified longitudinal drive cycle is generated by the Drive Cycle Source block. The output of the block is the longitudinal speed of the specified vehicle, which can be used to

- • Calculate a vehicle's engine torque and fuel consumption to reach the desired speed and acceleration using specified gear inputs.
- Create realistic velocity and shift references for closed loop acceleration and braking orders in vehicle control and plant simulations.
- Study tune and optimize vehicle control, system performance and system robustness over multiple drive cycles.
- Identify the faults with in tolerances specified by standardized tests, including EPA dynamometer driving schedules

G.Battery: The Battery block represents the battery model. The block calculates 0-load voltage as a function of charge level and comes with a variety of modelling choices. Self-discharge, Battery Fade, Charge Dynamics, and Charge Dynamics Ageing by the calendar are the four categories. The Battery (Table-Based) block has four modelling versions that may be accessed by right-clicking the block in your block diagram and selecting the relevant option from the context menu (under Simscape > Block options). Uninstrumented Instrumented Show thermal port with no instrumentation, instrumented show thermal port with instrumentation, and instrumented show thermal port with instrumentation The instrumented models offer an extra physical signal port that outputs the internal state of charges. This functionality allows you to adjust load behavior based on charge status without having to generate a charge.

H.Simple Gear: The Simple Gear block illustrates a gearbox with a set ratio between the coupled transmission shafts of the base gear, B, and the rear gear, F. can define whether the follower axis rotates in the same or opposite direction as the base axis. If the follower and the base rotate in the same direction, the angular velocity of the follower, F, and the angular velocity of the base, B, have the same sign. If F and B rotate in opposite directions, they have opposite signs. It's simple to add and eliminate backlash, flaws, and thermal effects **.**.

- The kinematic constrain that the Simple Gear block imposes on the two connected axes is
  $r_F \omega_F = r_B \omega_B$
  where:
  r_F is the radius of the follower gear.
  ω_F is the angular velocity of the follower gear. r_B is the radius of the base gear.
  ω_B is the angular velocity of the base gear.
- The follower-base gear ratio is

$$g_{FB} = \frac{r_F}{r_B} = \frac{N_F}{N_B}$$

where:
N_B is the number of teeth in the base gear.
N_{BF} is the number of teeth in the follower gear

Proposed Model:

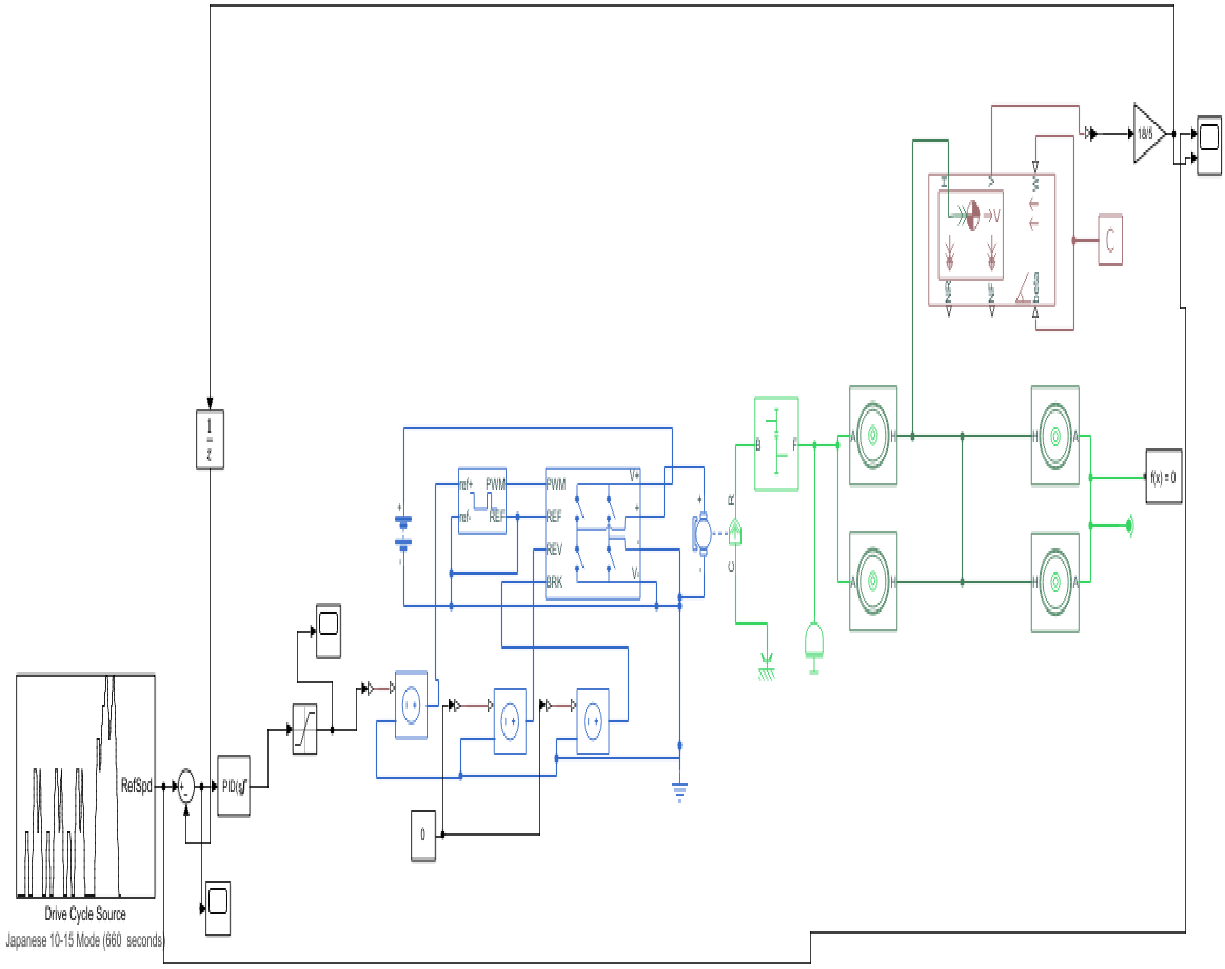

Figure: MATLAB SIMULINK MODEL of an Electric Vehicle

Simulation Results:

After designing and modeling the MATLAB SIMULINK was used to create an electric vehicle some simulation has to be performed in order to assess the electric vehicle battery capacity, range,speed ,and time for acceleration and deceleration, idle time, and cruise time. Also, according to the model, the main parameter is to plot the difference in the rated speed of the vehicle and the actual speed of the vehicle by taking feedback from the vehicle body.

- Simulation results of given input drive cycles are shown in figures A1 and A2.
- Simulation results of the PWM voltagesignalareshowninFiguresB1and B2.
- Simulation results of the velocity of rated and actual velocity fora giveninputdrivecycleareshowninFiguresC1, and C2

(1) ExtraUrbanDriveCycle:

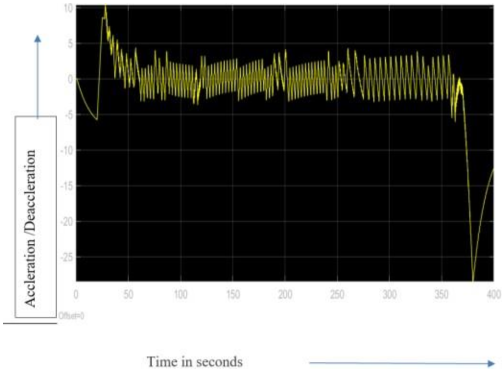

Figure:A1

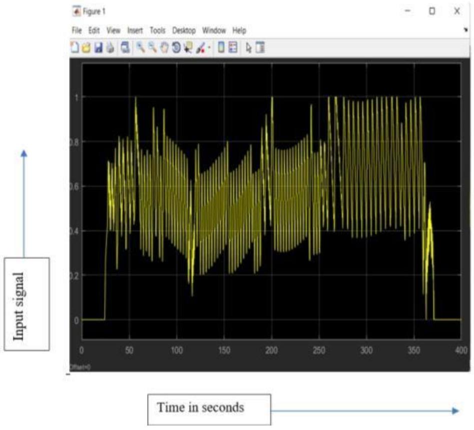

Figure:B1

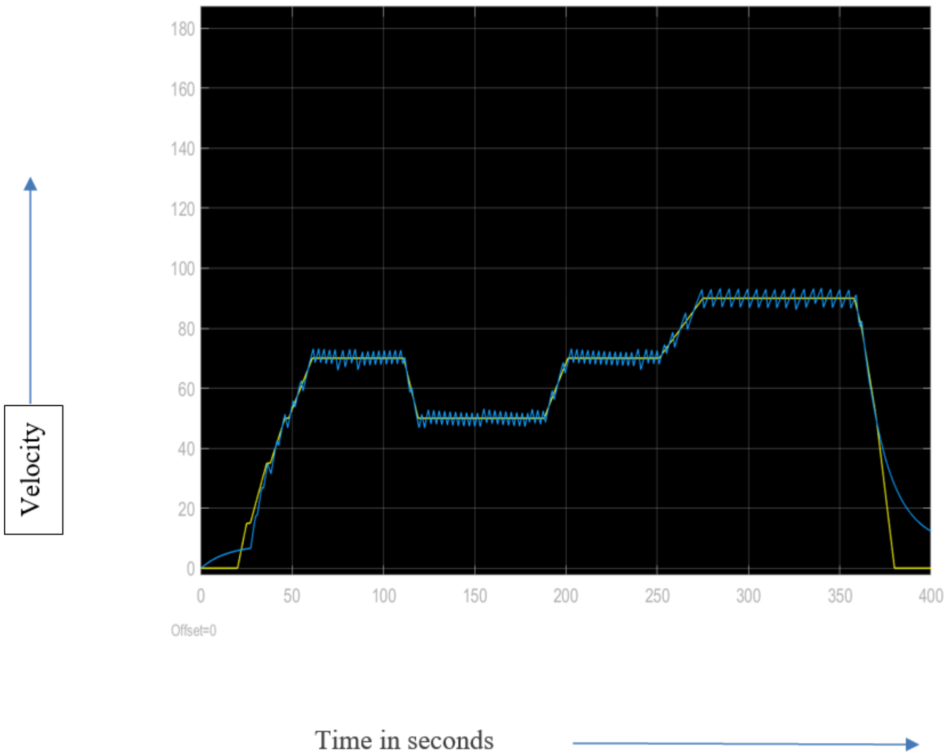

Figure:C1

(2) Japanese10-15ModeDrivingCycle:

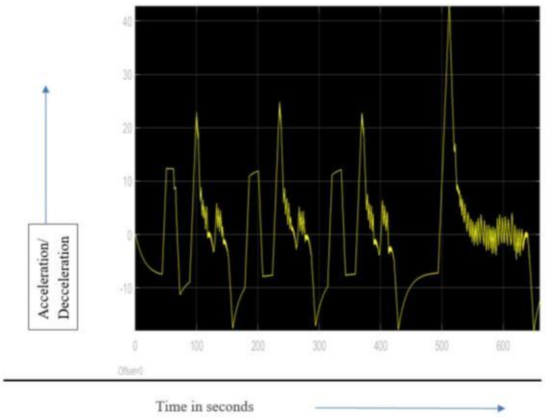

Figure: A2

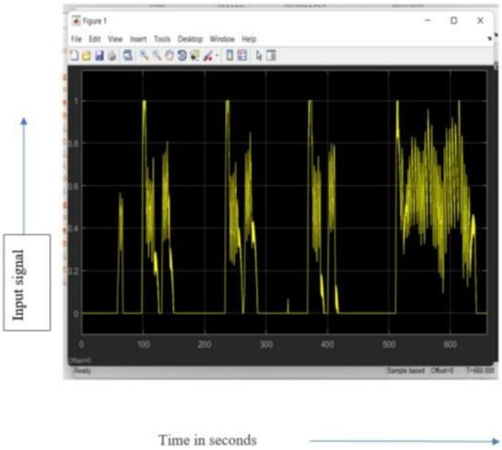

Figure:B2

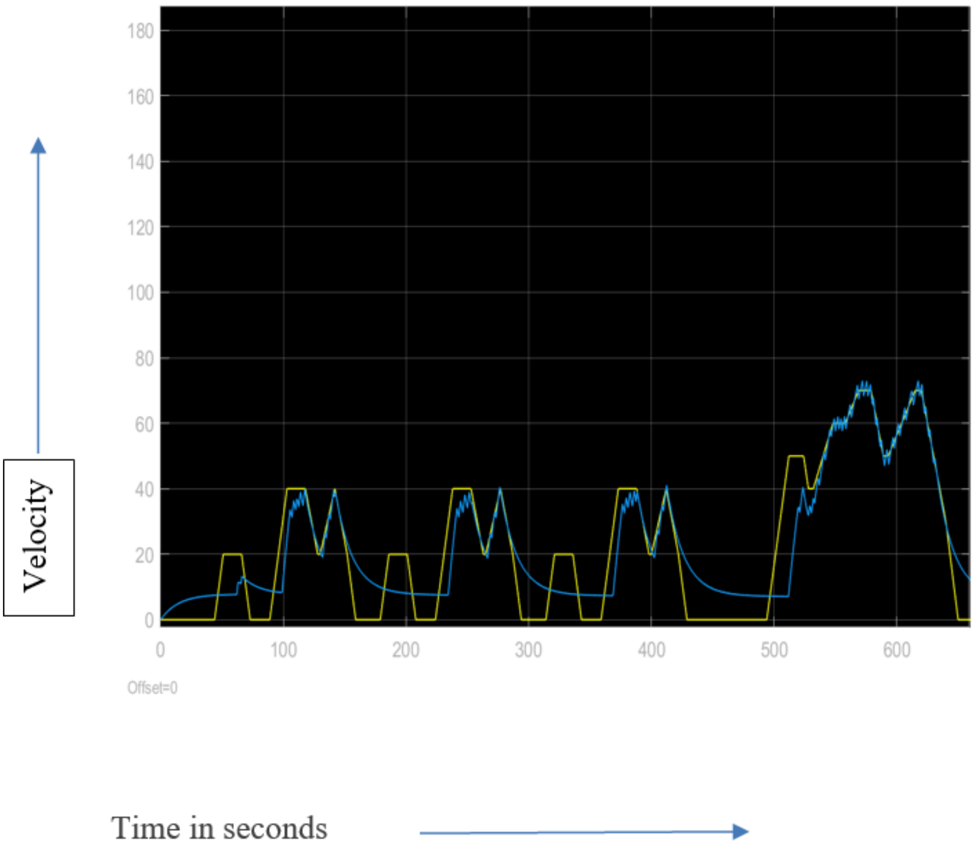

Figure:C2

Conclusions:

Modeling an electric vehicle system makes it simple to figure out how much battery capacity an electric car with specified specifications needs to travel a certain distance.

- This model can be used to measure the performance of a vehicle throughout the starting process or when running at a constant speed, as well as to estimate how long the battery can be utilized.
- In this project, we model an Electric Vehicle while taking into consideration its all the basic system of vehicle body parameters, DC motor, HB ridge, PID Controller, Driver Cycle input.
- We get the feedback input from vehicle body and we sorted it by using descret PID controller.

Reference:

- Electric Vehicle Battery Modeling and Simulation Using MATLAB Simulink Dr.A. Surana, Mrs. A. Srilatha, Mr. S. Suresh
- Modeling and Performance Analysis of an Electric Vehicle with MATLAB/Simulink Hitesh, C. Sunanda.
- Modeling of Electric Vehicles Using MATLAB/Simulink Marah AlHalabiandAnasAlTarabsheh
- AMATLAB-Based Tool for EV-Design G.N.Reddy
- Design and Development of Small Electric Vehicle using MATLAB/Simulink
- High Performance Electric Vehicle Powertrain Modeling, Simulation and Validation Feyijimi Adegbohun, Annettevon Jouanne, Ben Phillips, Emmanuel Agamlohand Alex Yokochi
- https://ev-database.org/car/1145/BMW-i3-120-Ah
- https://youtu.be/tM9Akdo8QeA
- https://youtu.be/xmdUFEfiAKk
- https://youtu.be/ih0UyVc6sJA
- K. Venkata Rao, Bachina Harish Babu, V. Umasai Vara Prasad, A study on effect of dead metal zone on tool vibration, cutting and thrust forces in micro milling of Inconel 718, Journal of Alloys and Compounds, Volume 793, 2019, Pages 343-351, ISSN 0925-8388, https://doi.org/10.1016/j.jallcom.2019.04.194.
- Babu, B.H., Rao, K.V. & Ben, B.S. Modeling and optimization of dead metal zone to reduce cutting forces in micro-milling of hardened AISI D2 steel. *J Braz. Soc. Mech. Sci. Eng.* **43,** 142 (2021). https://doi.org/10.1007/s40430-021-02861-5.
- M. Selvamuthukumar, B. Harish babu, Sujith bobba, S. Baskar, Nivin Joy, Investigation on the lubricating behavior of cashew nut shell liquid oil as a renewable and reliable petrochemical product, Materials Today: Proceedings, Volume 44, Part 5, 2021, Pages 3583-3588, ISSN 2214-7853, https://doi.org/10.1016/j.matpr.2020.09.458.
- Palakuru Mahesh , Sirisha Adamala , Harish Babu Bachina, Application of Space-Born Remote Sensing To Analyze Forest Cover in Chittoor (India) Area, International Journal for Research in Applied Science & Engineering Technology (IJRASET) ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor :6.887 Volume 6 Issue I, January 2018- Available at www.ijraset.com.

- Krishna Reddy, Y.V., Sirisha Adamala and Bachina Harish Babu. 2017. Case Study on Performance Evaluation of Drip Irrigation Systems in Selected Villages of Guntur District, Andhra Pradesh, India. Int.J.Curr.Microbiol.App.Sci. 6(2): 437-445. doi: http://dx.doi.org/10.20546/ijcmas.2017.602.049
- MAHESH PALAKURU, SIRISHA ADAMALA, & HARISH BABU BACHINA. (2020). Modeling yield and backscatter using satellite derived biophysical variables of rice crop based on Artificial Neural Networks. *Journal of Agrometeorology*, *22*(1), 41–47. https://doi.org/10.54386/jam.v22i1.120.
- P. Manoj Kumar , Bachina Harish Babu, S. Gowtham & K. Rajesh, Development And Study Of Tribological Properties Of Bio composite For Brake Pad Application, International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) ISSN (P): 2249-6890; ISSN (E): 2249-8001 Vol. 7, Issue 6, Dec 2017, 263-270.
- M Shri, Bachina Harish Babu, V. Harish, Syed Riyaz Ahammed, R Hushien, Manoj Kumar, Optimized Water Pumping System Using Arduino For Home Automation, International Journal of Mechanical Engineering and Technology (IJMET) Volume 8, Issue 8, August 2017, pp. 1412–1416, Article ID: IJMET_08_08_145 Available online at http://iaeme.com/Home/issue/IJMET?Volume=8&Issue=8 ISSN Print: 0976-6340 and ISSN Online: 0976-6359.
- Bobba, S., Selvamuthukumar M.,, Harishbabu, B., & Leman, Z. (2022). Solar-Based Mosquito Trap for Household Purposes. *International Journal of Social Ecology and Sustainable Development (IJSESD), 13*(1), 1-10. http://doi.org/10.4018/IJSESD.288536
- Sujith Bobba, Z. Leman , B. Harish Babu, Environmental effects on the mechanical properties of E-glass and S-glass fiber epoxy composite ring specimens used in aircraft fuel pipes, Incas Bulletin, Volume 13, Issue 4/ 2021, Pp. 17 – 24 (P) Issn 2066-8201, (E) Issn 2247-4528.
- Bobba, S., Mukkollu, S. R., Leman, Z., & Bachina, H. B. (2021). Experimental Investigation on the Effect Due to Mould Vibrations on Mechanical and Metallurgical Properties of Aluminum Alloy (A-1050). *International Journal of Surface Engineering and Interdisciplinary Materials Science (IJSEIMS), 9*(1), 77-86. http://doi.org/10.4018/IJSEIMS.2021010105.
- Bachina Harish Babu, Dillip Kumar Sahoo, Study of Tribological and Thermal Properties of Engine Lubricant by Dispersion of Aluminium Nano Additives**. ,** Revue des Composites et des Matériaux Avancés, Apr2020, Vol. 30 Issue 2, p103-107. 5p.
- Sujith Bobba, Mukkollu Sambasiva Rao, B. Harish Babu, Z. Leman (2020). Effect on the Mechanical Properties of Grey Cast Iron with Variation of Molybdenum and AS – Cast Alloying Elements. Universal Journal of Mechanical Engineering, 8(6), 298 - 304. DOI: 10.13189/ujme.2020.080602.
- R Prabhu, Bachina Harish Babu, M Selvamuthukumar, N Poiyyamozhi, Nanocomposites in food packaging, Int. J. Recent. Technol. Eng 2, 2277-3878.