Modeling of E-ATV Using MATLAB/SIMULINK

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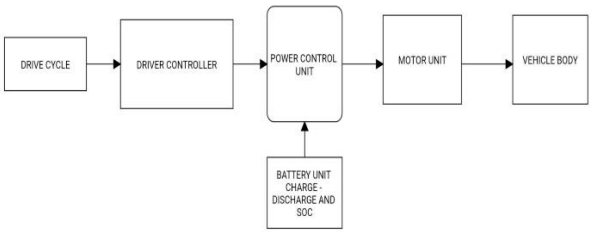
***Abstract*— The paper presents the modeling of electric vehicles for all-terrain operation with the help of MATLAB Simulink software to increase the performance and range of electric vehicles. Preliminary studies are done on the power and torque requirements of electric ATVs. A complete simulation model of the mechanical load is developed and it is then combined with a comprehensive electronic drive. control unit and PMS motor simulation using MATLAB SIMULINK. We have developed an E-ATV model from the simulation result with the help of a battery pack controller unit and motor unit with a protective circuit.**

Keywords—E-ATV, MATLAB, SIMULINK, FTP75.

I. INTRODUCTION

Electric vehicles are emerging as viable solutions to address urban pollution, greenhouse gas emissions, and the depletion of finite fossil fuel resources, collectively known as the challenging triad. These vehicles utilize centrally generated electricity as their power source, which offers several advantages. Power generation at centralized plants is more efficient and allows for easier control of emissions compared to internal combustion engines dispersed worldwide. Moreover, electric vehicles can convert kinetic energy into electrical energy and store it during braking and coasting. The numerous benefits of electric vehicles have caught the attention of industry, academia, and policymakers who now, consider them promising alternatives for urban transportation, a century after their initial introduction. However, the widespread adoption of electric vehicles faces barriers such as battery pack, lifespan, energy density, power density weight, and cost it's crucial to address these challenges while also emphasizing the modeling and optimization of other vehicle components as they significantly impact efficiency drivability, and safety. The growing demand for knowledge in modeling and optimizing electric vehicles reflects in industry and academia's determination to overcome these barriers and maximize the vehicle's potential.

Fig.1 - Vehicle Block Diagram.



This paper focuses on the step-by-step modeling and simulation of electric vehicle and their components, with valuable contributions from researchers in both technical and regulatory domains. The aim is to provide a comprehensive guide for industry, academia, and policymakers. The research combines mathematical models for electric vehicle and their components to create cohesive resources. The papers effective less is ensured by a logical structure. it begins by examining dynamic models and simulation results for electric vehicles and traction systems. Next models for alternative electric motors and drive systems are presented. This is followed by an exploration of models for power electronics components and various control systems. Finally, an intelligent energy management system is introduced to provide a holistic understanding of the subject matter.

II. LITERATURE REVIEW

1. Mauridhi hery Purnomo (June 2011) represented a design and development of a small electric vehicle using MATLAB Simulink, Thepaper'sr concerned with the modeling of an electric vehicle system makes it easy to determine how much battery capacity required by an electric vehicle with the help of MATLAB Simulink. This also enhanced the performance of electric vehicles such as the starting process or running with constant speed. [1]
2. Ahmet Onur Kiyakli (2018) presented modeling of an electric vehicle with MATLAB Simulink, this paper considers simulation result including a NEDS and

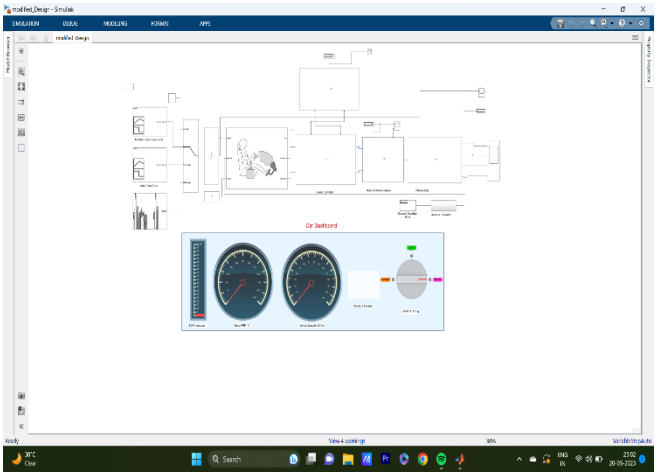
WLTP cycle, which understand that vehicle speed and cycle speed is similar also the energy consumption data obtained from the model is determining the charge state of the battery. [2]

3. Omar Horan (Sep 2022) presented the modeling and design of a quadcopter with MATLAB implementation. This paper considers developing a simple modeling approach using MATLAB Simulink the vehicle Simulink model is based on deriving a differential Simulink model simulated perfectly depending on the equation of the motion, also the quadcopter is an aerial vehicle they demonstrate how to model a basic physical quadcopter. [3]
4. Hitesh s' (June 2020) represented modeling and performance analysis of an electric vehicle with MATLAB Simulink, this paper guides the step-by-step analytical calculation of an electric vehicle. This observation can be utilized to improve the range of EVs, this paper was explaining the vehicle terminology and its analytical calculation, furthermore, the effect of various parameters on vehicle performance was analyzed. This paper was intended to be a ready reference for basic calculation and simulation of the EV model. [4]
5. Shivangi Kaushik (Aug 2019) This paper considered optimizing the cost and range of electric vehicles with the help of MATLAB/ Simulink and also the configuration of electric vehicles with and without WOA Optimization analyzed to show the feasibility of the EV drive system model. The synchronization and controlling of the drive system are achieved by the conventional un-optimized PI controller. [5]
6. Radhika V. Deshmukh (March 2023) represented modeling and simulation of a battery of an electric vehicle by using MATLAB simulation, this paper considers the observed operation of several types of power electronics converters to determine the motor torque and brake pressure commands also to develop a simulation model of electric vehicle car with functional blocks. [6]
7. Samar Sawant (October 2022) presented a simulation of an electric truck on MATLAB Simulink. The primary objective of this paper is the EV energy consummation through a simulation of a custom-designed electric vehicle, furthermore, the quick creation of a physical framework model is enabled using Simulink software with this physical part model support association that directly integrates with a block diagram. The drive cycle of this paper is a speed VS time plot with provides acceleration and deceleration commands to the controller to provide through the transmission. Also, the paper consisted of electric power train design and components selection according to constraints and surrounding conditions required for vehicle performance. [7]
8. Schaltz (2011) represented electric vehicle design modeling and simulation also the model of each component of the power system in the electric vehicle has been explained also the overall vehicle model includes the model of the forces acting on the vehicle and individual components of the power train have been calculated in this result paper. [8]
9. Adam R. Cheverfils (2008) presented the modeling and design of an electric all-terrain vehicle. This paper considered an electric power train vehicle's initial components analyzed for the calculation of the transmission system and Matlab Simulink analysis is provided which is most of the time useful for evaluating the electric drive system and simulation, also provides a testing summary and observation of MATLAB Simulink model. [9]

III. VEHICLE MODELING

The proposed vehicle model presented in Fig 1, is developed by using the drive cycle, motor and gearbox, controller model, and battery model in MATLAB. The electric machine will start delivering traction power to the wheels continuously. The differential, which includes a gear ratio distributes torque to the left and right wheels, adapting the high speed of the electric machine shaft to the lower speed required by the wheels. The inverter controls the torque and speed of the electric machine by converting the battery DC voltage into a three-phase AC voltage suitable for the machine. when assessing the energy consumption of electric vehicles, it is crucial to consider losses incurred by components outside the power transmission path from the grid to the wheels. these losses, referred to as auxiliary encompass systems such as lighting comfort and safety during regenerative braking it is essential to prevent the battery from exceeding its maximum voltage to address this a braking resistor is employed the rectifier converts the three-phase voltages and current from the grid into DC levels, and the boost converter enables power transfer from the low voltage side of the rectifier to the high voltage side of the battery.

Fig.2 - Vehicle Load Model:



- Vehicle dynamic calculation and analysis

The vehicle dynamic compromises of the three forces acting on the vehicle.

1. Rolling resistance
2. Gradient force
3. Aerodynamic drag

For calculating these forces some consumption is made expressed as given data following,

a) Gross vehicle weight = 280 Kg
b) Air density ρ, at 15^0 = 1.225 kg/m^3
c) Coefficient of drag =0.4 [cd]
d) Rolling Resistance coefficient μ = 0.05
e) Gradient angle = 5
f) Radius of wheel = 0.292
g) Gravity = 9.81 m/s^2
h) Area = 0.839 m^2
i) Velocity = 50 kmph i.e. 13.88 m/s

1] Rolling resistance

The rolling resistance i.e. rolling friction or rolling drag is a force acting on the vehicle which is resistant once the motion when a body roll-on a surface the rolling resistance is calculated by,

Rolling resistance = μ. m.g.
= 0.05*280*9.81
= 137.34 N ---------- F_{roll}

Rolling resistance is nothing but the energy that your vehicle required to rotate the tires to maintain continuous movement at a consistent speed over a surface i.e. on the effort required to keep the tire rolling.

2] Aerodynamic drag

Aerodynamic drag force is defined as the force which is faced by the vehicle as it moves through the air. This drag force depends mainly on the front area of the vehicle, side mirrors ducts, and many other factors.

Aerodynamic drag is calculated by,

$$\text{Aerodynamic drag} = \tfrac{1}{2}\ \rho\ A\ Cd\ v^2$$

Where,
ρ = Is the air density
A = is the frontal area of vththeicle
Cd = is the coefficient of drag
V = is the velocity in m/s

Aerodynamic force = ½*1.225*0.839*0.4*$(13.88)^2$
= 39.60 N ---------- F_{ad}

3] Gradient force

The third force that acts on a vehicle is the gradient force the force occurs when the vehicle is driving on uphills or downhill roads the gradient force is due to the longitudinal components of gravitational force, namely mg where theta (?) is the inclination angle of the road.

The gradient force is calculated by,

Gradient force = m.g sin ϕ
= 280*9.81*sin $(5)^0$
= 239.39 N ----------F_{grad}

The gradient force is calculated from the weight acting at the center of gravity

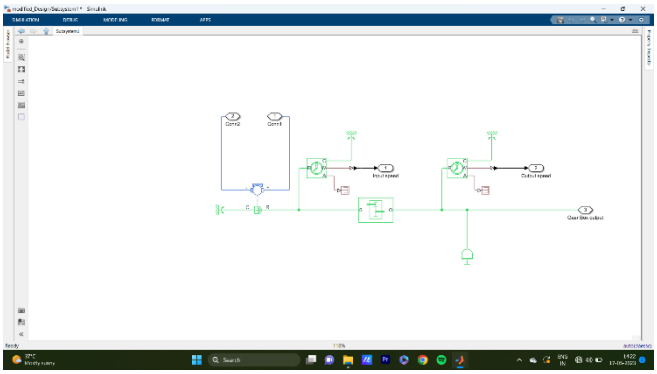
The total force acting on a vehicle is given by

$\therefore$ F_{total} = f_{roll} + f_{ad} + f_{grad}
= 137.34 +39.60+239.39
= 416.33 N

$\therefore$ The power required by the forces will be

P_{roll} = 137.34* 13.88 = 1906.2792 W
P_{ad} = 39.60* 13.88 = 546.648 W
P_{grad} = 239.39 * 13.88 = 3322.7332 W

Fig.3 - Motor Model:

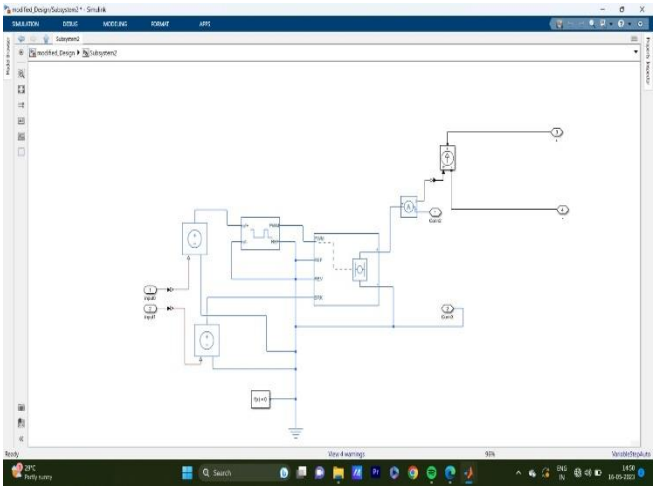


The block fig represents a motor model of the terminal with electrical and torque characteristics. The voltage sensor is connected parallel to the PM motor. The block assume that no electromagnetic energy is lost, and hence the back emf and torque constants have the same numerical value when in SI units. motor parameter can either be specified directly or derived from no load speed and stall torque if no information is available on armature inductance, this parameter can be set some small non zero value. When a positive current flows from the electrical + to – ports, positive torque acts from the mechanical C to R motor torque direction can be changed by altering the sign of the back emf of torque constants.

- Motor-rated voltage = 48v dc supply
- Motor-rated electrical power = 6 kw
- No load speed = 4500 rpm
- Rated load speed = 3000 rpm
- Armature inductance = 42.5 mh
- Armature resistance = 0.384 ohm
- Rotor inertia = 5.4 kg.m^2.10^{*3}

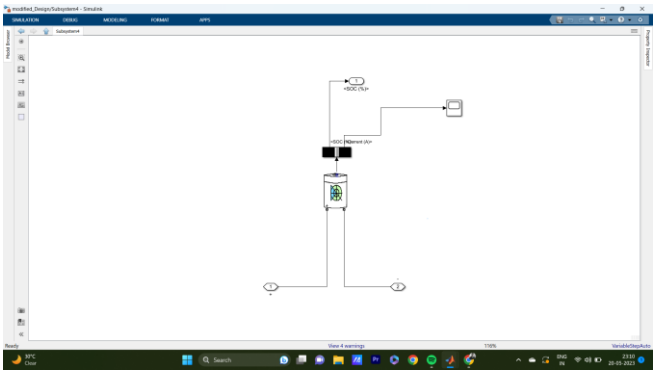
The C port i.e. casing is connected with mechanical rotational reference The r port i.e. rotor connected with a simple gear transmission block of the vehicle body subsystem.

Fig.4 - Controller Model:



This block creates a pulse-width modulated (PWM) voltage across the PWM AND REF ports. The output voltage is zero when the pulse is low, and is equal to the output voltage amplitude parameter when high at time zero, the pulse is initialized as high unless the duty cycle is set to zero or the pulse delay time is greater than zero.

Fig.5 - Battery Model



The following tables configured the parameter selection for the vehicle load model and motor load model also for the battery load model.

Table No.1 Vehicle body

Sr. No	Parameter	Value
1	Gross vehicles weight	280 kg
2	Load carrying capacity	50 kg
3	Rolling resistance coefficient	0.05
4	Aerodynamic drag coefficient	0.4
5	Frontal value	0.839

Table No.2 Drive train

Sr. No.	Parameter	Value
1	Power train	Rear wheel drive
2	No. of motor	1
3	Motor type	PM MOTOR
4	Efficiency	95
5	Maximum speed	4500
6	Rated speed	3000
7	Rated torque	25NM
8	Rated power	6 KW
9	Rated current	125 AMP

Table No.3 Transmission Parameter

Sr. No.	Parameter	Value
1	Type	Single
2	Simple fixed gear ratio	8.5:1
3	Front/rear	580 mm

Table No.4 Battery configuration

Sr. no	Parameter	Value
1	Battery	Lithium-ion
2	Nominal cell voltage	3.6
3	Nominal battery pack voltage	48 volt
4	Nominal battery pack capacity (Ah)	120 Ah
5	Nominal battery pack energy (Kwh)	5.7 kWh
6	Weight	45kg

IV. RESULT

In the result section, we discussed the speed profile comparison with reference speed fed to the system by the FTP75 drive cycle. The reference speed is taken from feedback of the system and the plot is shown below in Fig. 6. Furthermore, the distance plot shows the distance traveled by the vehicle at a reference time interval. The result of battery discharging i.e. state of charge is also shown in Fig. 5 at the start of the vehicle the battery is charged up to 90%. After starting the simulation for 2400 sec. Its discharge is up to 77% from 90%, covering a distance of 15.01 km.

Fig.6 – SOC Output

In Fig. 5 at the start of the vehicle's battery, charge up to 90 % .as the vehicle starts moving, the battery starts discharging as shown in Fig 5. And when brakes are applied the graph in fig 5. Will start to increase as shown in Fig 5. This is known as regenerative braking

Fig.7 - Velocity output with reference output (km)

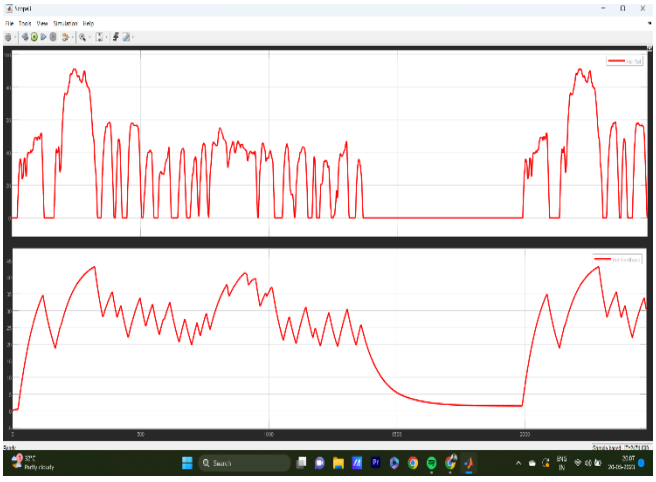


Fig.8 – Speed output with the reference speed

Fig.9 – Longitudinal force, distance, speed, and velocity output.

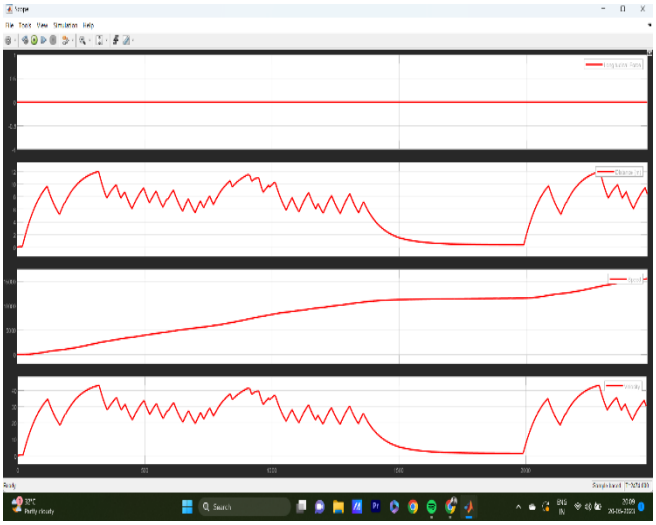


Table.No.5 Result Table.

Sr.no	Parameter	Value
1	Drive Cycle	FTP 75
2	Initial SOC State	90 %
3	Final SOC State	77 %
4	Reference Velocity	90 kmph
5	Velocity Feedback	43 kmph

V . CONCLUSION

The paper is about the simulation using MATLAB software for electric vehicles. By using the simulation method, we can conclude the approx. performance result of the respective electric vehicle. This method is used in research and development (R&D) to specify the result before directly manufacturing the vehicle. Vehicle dynamic, electric rating, and thermal ratings are considered to run this simulation. A direct model representing the vehicle body power train and energy storage system is made where given data used as input various drive cycles can be used to test the simulation model. We used the FTP75 drive cycle which gives watt/hr. per km, the energy consumption efficiency of every component considers its nominal value this way the obtained result is really up to the sum intended.

VI. REFERENCES

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