

Design of E-Rickshaw using MATLAB

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Abstract— The current environmental apprehension is fascinating the world to swift towards green technology. Electric Vehicles(EVs) are an alternate means of transport for future as they have great potential to minimize the use of petrol based and other transport fuel that emits high CO₂. The Battery-operated Electric Rickshaw is an alternative option to replace the auto rickshaw as it is environment friendly and the overall system cost is much less than conventional auto rickshaw. In this paper a simulation model of Electric rickshaw using MATLAB with the Performance analysis of E-Rickshaw for different drive cycle were presented.

Keywords— E-Rickshaw, Electric vehicles (EVs), State of charge(SOC).

I. INTRODUCTION

In present days air pollution became a serious problem in the metropolitan cities. One liter of gasoline produces approximately 2.3kg of Carbon dioxide, this means that average vehicle burns 2000 liters of gasoline every year, releases about 4600kg of carbon dioxide into the atmosphere.so the Battery powered vehicle is considered as a solution for environmental pollution and energy crisis. The Automobile sector, propelled by internal combustion engine is gravitating gradually towards Electric Vehicles (EVs) in order to mitigate the effects of fossil fuel emission and addresses environmental concern. Electric Vehicles are being promoted aggressively all over the world.

Auto rickshaws are three wheeled vehicle that are extensively used in many Asian countries as taxis for the people and goods. These three wheeled vehicles play the most important role as public, private and para-transit modes of transportation and they are suited to the Indian traffic environment.

The Extortive literature survey was done which shows that automotive industries of all over the world uses the SIMULINK for design control system for automotive for traditional petrol/diesel operated vehicles to hybrid vehicles and electric vehicles for analysis and performance enhancement of vehicle, some of this is as under: The model of Lithium- ion battery with the dynamic characteristics have been proposed in[4]. To determine the effect of different drive modes as acceleration, deceleration and cursing on the energy consumption of an Electric Rickshaw along with the drive cycle analysis to analyze the energy consumption during vehicle operation is explained in[7]. The dynamic model of electric vehicle and the regenerative braking control at the time of deceleration so that the kinetic energy is not wasted and that amount of energy is used for the battery which can increase the electric vehicle range is explained in[8]. The modelling of component uses to design electric vehicle is explained in[12].

This paper, discussed the design and simulation of E-rickshaw with its relevant system component with the performance analysis for different drive cycle by using MATLAB.

II. COMPONENT OF E-RICKSHAW

A. Vehicle dynamic modelling

The tractive effort or force of the E-rickshaw is the force driving in the vehicle forward which get transmitted to the ground through the drive wheels [8]. By using Newtons law of motion, the vehicle is modelled as a load by

considering various longitudinal forces acting on it[2], which is depicted in fig1.

$$F_t = F_{rr} + F_{ad} + F_{hc} + F_{la} + F_{wa}$$

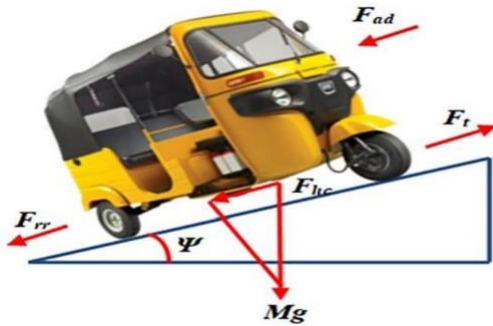


Fig.1 Forces on E-Rickshaw

The tractive force F_t required to drive the wheels by overcoming resistive force is given by,

$$\dots\dots(1)$$

Where F_{rr} is the rolling resistance force, F_{ad} is the aerodynamic drag, F_{hc} is the hill climbing force, F_{la} is the linear acceleration force and F_{wa} is the rotational acceleration force. The extended form of equation(1) is given by

$$F_t = C_{rr} m g + \frac{1}{2} \rho A C_d v^2 + m g \sin \theta + M \frac{dv}{dt} + 0.1 F_{la} \dots\dots(2)$$

Where, C_{rr} is the rolling resistance coefficient. m is the mass of the vehicle (Kg), a is the gravitational constant

(9.81m/s²), Ψ is the grade angle (degree), ρ is the density of air (1.22kg/m³). A , is the frontal area of E- Rikshaw, v is the velocity in m/s. C_d , is the drag coefficient.

Using the obtained instantons tractive forces and the speed of vehicle, the tractive power required at wheel is calculated as

$$P_t = F_t \times v \dots\dots(3)$$

B. Modelling of lithium- ion battery

The battery is very important component of whole electric vehicle system. Lithium ion batteries provide high range with less charging time which is essential for electric vehicle. Also it requires lower maintenance and having long life cycle. It provide 90-95% efficiency. Li-ion battery model is also essential to predict the battery behaviour under various operating condition and to estimat the battery state of charge (SOC) [7]. The 100% state of charge is chosen as a reference state of charge for Li-ion cells.

An equivalent electrical circuit of Li-ion battery is shown in fig 2.

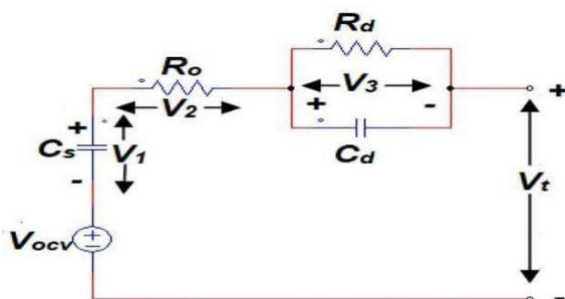


Fig.2 Equivalent Ciciuit of Li-ion Battery

The circuit consist of open circuit voltage of the battery (V_{ocv}), series resistor (R_o) represent the ohmic resistance drop. The storage capacitance is represented by a series capacitor (C_s). The parallel RC branch account for the diffusion charge, where (R_d) represent diffiusive resistance and (C_d) represent diffusive capacitance. V_t is the terminal voltage of the battery as measured accros it terminal given by

$$V_t = V_{ocv} - V_1 - V_2 - V_3 \dots\dots(5)$$

The state of charge (SOC) is a relative measure of the amount of energy stored in a battery, define as the ratio between amount of charge extractable from the battery at the specific time and the total capacity. The below equation shows the ratio between the residual charge allowable and the nominal capacity is the state of charge of the battery.

$$SOC = \frac{Q(t)}{Q(nom)} \dots\dots(4)$$

Where, $Q(t)$ is the ratio between the residual charge available and ($Q(nom)$) nominal capacity. The battery pack having terminal voltage of 48 volt is directly connected to the motor drive. The battery is assumed to operate with SOC from 30% to 100%, with an initial SOC of 80%.

C. Modelling of Motor

The motor and Power converter system are the major consideration while designing an Electric vehicle. As electric motor converts electric energy into mechanical energy that mechanical energy is delivered to wheels via a transmission system. The Brushless dc motor (BLDC) is preferred as it is intended for light electric vehicle. It exhibits better performance in terms of efficiency, fast response, high torque and easier maintenance.

The maximum power of the motor is 485.7 kW. But the motor can be overrated almost 1.75 or 2 times for few seconds[3]. So, an 850 kW BLDC motor has been chosen to meet the power requirement at acceleration and during grading of road. The motor speed or the wheel speed are varied by the gear ratio(GR)[6] which is given as

$$GR = \frac{N_m \times r_w \times \pi}{30 \times V_{max}} \dots\dots(6)$$

Where, N_m is the maximum motor speed, r_w is the wheel radius and V_{max} is the maximum velocity of the vehicle. The required wheel torque can be calculated from

$$T_{req} = F_t \times r_w \dots\dots(7)$$

III. TECHNICAL SPECIFICATION

In this study, the technical specification of Bajaj E-Rickshaw is used.

TABLE 1. VEHICLE SYSTEM SPECIFICATION

Parameters	Description
Kerb weight, Mass	600 kg
Coefficient of rolling resistance (Crr)	0.015
Drag Coefficient (Cd)	0.5
Frontal Area(A)	2.09m ²
Gradeability	18 Degrees
Air density	1.22kg/m ³
Speed (Kmph)	45

TABLE 2. MOTOR SPECIFICATION

Parameters	Description
Motor Type	Brushless DC Motor (BLDC)
Rated Current	25A
Rated Power	850KW
Rated Speed	320 rpm

TABLE 2. BATTERY PARAMETER

Parameters	Description
Battery Type	Lithium-ion
Rated Voltage	48volt DC
Rated current	100AH
Charging time	4-8 hrs

IV. SIMULATION MODEL OF E-RICKSHAW

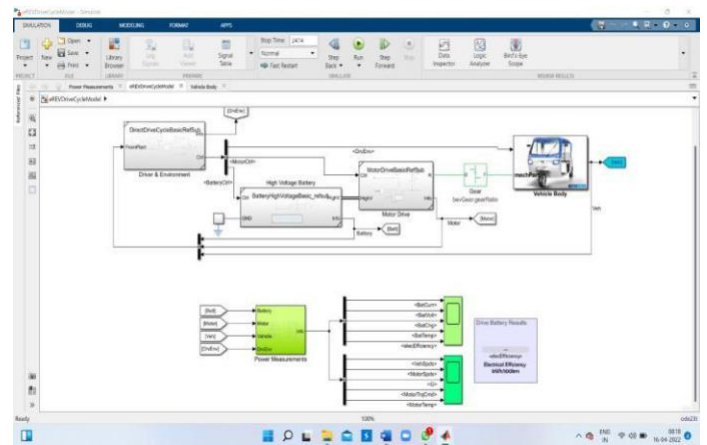


Fig.3 Complete Model of E-Rickshaw

The simulation model consists of four main components: The vehicle body, motor and controller, Battery pack, power converter and Drive cycle source, as shown in fig.3.

Battery pack is the powerhouse for the E-Rickshaw which supplies power to motor. Power converter converts energy which is input from battery to an optimum level as required by the motor. Converter is bi-directional which helps to store energy in battery while deceleration. Vehicle

body represents the body of vehicle with wheels which are connected to the motor via a transmission system. Motor takes power from the battery as per load requirements with the help of controller. Driving cycle source is a reference driving pattern selected for the simulation.

V. RESULTS

The simulation model of E-Rickshaw has been created by the mathematical equations that are applied in all subsystem block. Simulation of E-Rickshaw was done with Federal test procedure (FTP-75) and Wide-open throttle (WOT) drive cycle and results are shown below. The fig.4 shows the voltage, current, temperature of Battery.

1. For Federal test procedure (FTP-75) Drive cycle

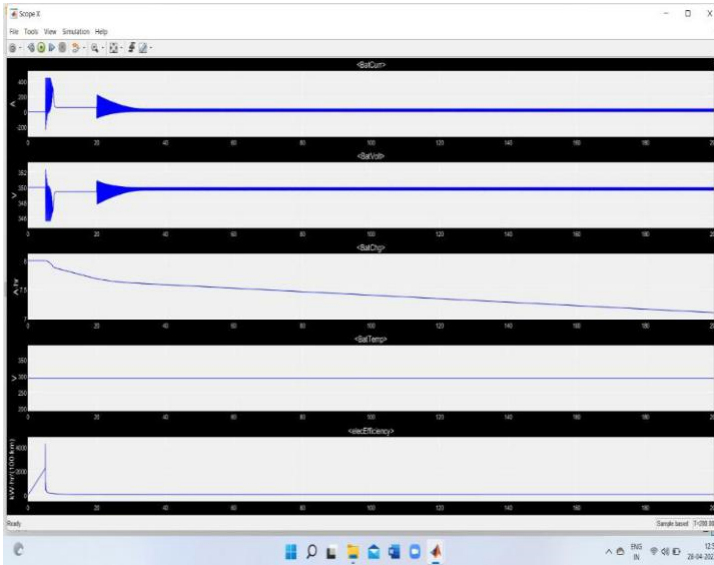


Fig.4 Battery performance characteristics

2. Wide open throttle

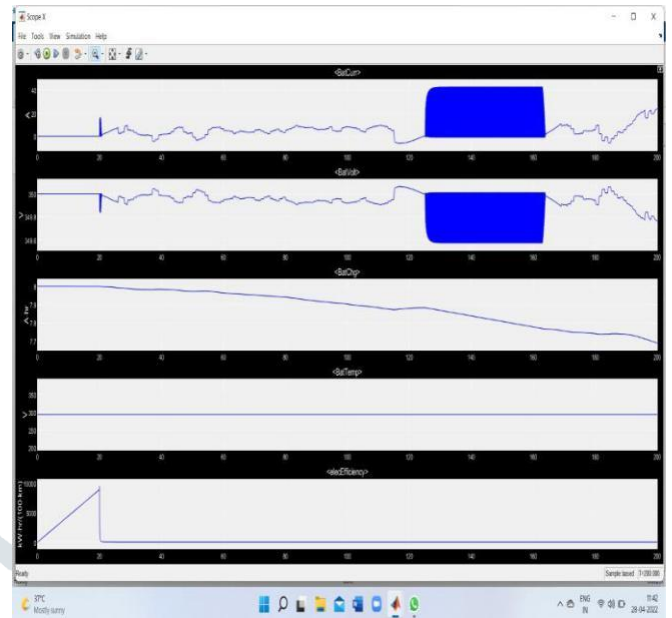


Fig.6 Battery performance characteristics

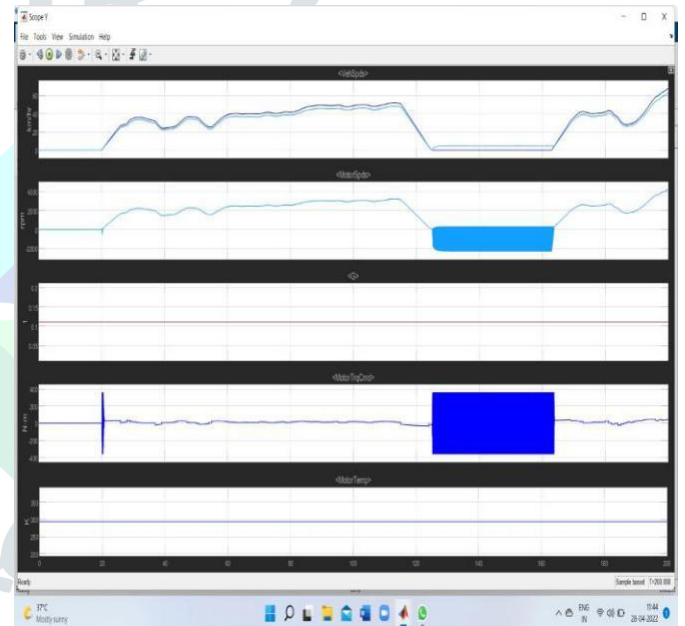


Fig.7 Motor performance characteristics

As the Electric rickshaw starts running the output is clearly visible through this simulation output waveform results.

VI. CONCLUSION

Modelling and simulation are very important to the automotive designers in order to find best energy control strategy, exact components size and to minimize the use of energy, because prototyping and testing are expensive and complex operation. In this paper, the Electric Rickshaw with its relevant components have been simulated in order to examine the energy consumption, performance of E-Rickshaw for the federal test procedure (FTP-75) and Wide-open throttle (WOT) drive cycle.

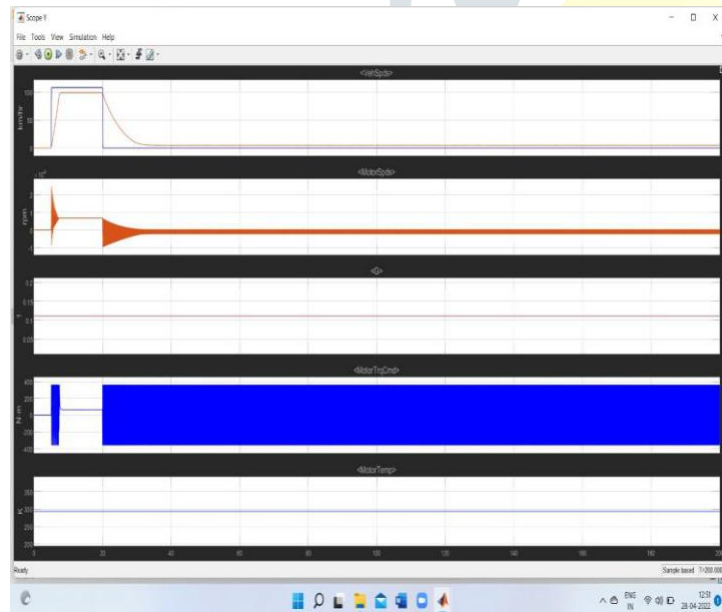


Fig.5 Motor performance characteristics

VII. ACKNOWLEDGEMENT

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