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E-Rickshaw Simulation in SIMULINK Software

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1. Abstract

Electric Rickshaw also known as E-Rickshaws are sustainable and cost-effective mode of transportation used in these days. These Rickshaws are highly efficient for short distance travelling and are famous in urban and semi-urban regions. The use of e-rickshaws aids in the global shift to sustainable energy in transportation and lowers carbon footprints. Through infrastructure construction, incentives, and policies focused at sustainable urban mobility, governments and commercial groups are encouraging their use. In this article, an electric rickshaw is modeled using Simulink software, and its performance is examined throughout two distinct driving cycles with variable dc motor specifications. This analysis is necessary to ascertain how motor characteristics relate to vehicle performance, which factors enhance vehicle performance, and how this can be accomplished. The research offers guidance on how to optimize motor characteristics to improve the dependability and efficiency of vehicles. This method aids in the creation of economical and energy-efficient solutions by highlighting the connection between motor design factors and the overall performance of electric rickshaws. For producers and researchers aiming to create sustainable transportation systems, the results provide insightful advice.

Index Terms: Electric Rickshaw, E-Rickshaw, Sustainable Transportation, Simulink Modelling, DC Motor Parameters, Driving Cycles, Energy Efficiency, Carbon footprint Reduction, Cost effective transportation.

2. Introduction

Increased air pollution has boosted research into improving air quality across the country. And idle petroleum sources that have been holding back economic growth over the past few decades have raised the need to identify other fuel-efficient vehicles. The electrification of transport has been identified as a potential solution to all the problems that the country faces in the current decade and in the future.[1] 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.[2] Electrical installation in autorickshaws can lead to better and cleaner urban public transport systems and may entice the public to opt out due to improve convenience, safety and travel cost has been done on the mixing of energy sources in the E-rickshaws in India which is the catalyst for this work [1] Due to less human effort and cost of fuel E-rickshaw is a good option if compared with auto rickshaw and human pulled rickshaw.

The pollution coming out from E-rickshaw is immensely less and it provides last mile connectivity that means it provides door to door service. Recently in India battery operated E-rickshaw have arrived [3].

Rickshaw went through many evolutions from the time it was invented. It is believed to be originally invented in Japan around the 1869. Its journey started from its first stage hand pulled rickshaw to cycle rickshaw to auto rickshaw and now it has reached to e-rickshaw. E-rickshaw came in number of models. These rickshaws have a MS tubular Chassi and it has three wheels with a differential at the rear wheels. The DC motor is brushless and is manufactured in India or China. The electric system uses 48V which is used in India. Fiber provides strength and durability which results in less maintenance so they are also becoming popular in e-rickshaw manufacturing [3]. From a technical standpoint, energy efficiency and simplicity are key design elements of electric rickshaws. To guarantee dependable operation, the drivetrain consists of a DC motor, battery pack, and rudimentary control system. The range and charging efficiency of these cars have been further enhanced by developments in battery technology, including as lithium-ion batteries.

As the world moves toward greener energy options, e-rickshaws are a prime example of how sustainability and useful mobility can coexist. Their use greatly lowers carbon footprints and aids in the global shift to more environmentally friendly urban mobility options. Due to their effectiveness as a last-mile connectivity option, these cars are especially well-liked in metropolitan and semi-urban areas. By providing incentives, subsidies, and infrastructure assistance to stimulate the adoption of e-rickshaws, governments and corporate players have played a critical role in their promotion. Because of their low cost, e-rickshaws are widely available to a variety of users and provide a living for drivers in many areas.

3.System Modelling

The following mechanical body parameters were taken into consideration as the reference on which analysis was conducted in order to construct a model of an electric rickshaw.

Table 3.1 Parameters of Vehicle Body

Specifications	Values
Mass	610 kg
Wheels per axel	02
Horizontal distance from CG to front axel	1.4 m
Horizontal distance from CG to rear axel	1.6 m
CG height above ground	0.33mm
Frontal Area	2.0 m^2
Drag Coefficient	0.5
Air Density	1.22 kg/m^3

The overall block diagram of the Simulink model of an electric rickshaw is shown in the figure 3.1 below. It can be seen that the drive cycle provides the longitudinal driver with information about the necessary vehicle speed, and the longitudinal driver uses this information to send a signal to the controlled PWM voltage block. The battery supplies energy to the controlled PWM block, which then transfers that energy to the H bridge in response to a signal from the longitudinal driver. Here, the H bridge serves as a power controller for the DC motor, which is attached to the vehicle's body and tires. Vehicle tire torques and DC motor speed are calculated. The DC motor, battery, drivetrain, and vehicle dynamics are just a few of the parts of an e-rickshaw that can be seamlessly integrated using Simulink. This all-encompassing method makes it possible to develop a thorough model that accurately depicts behavior in the real world.

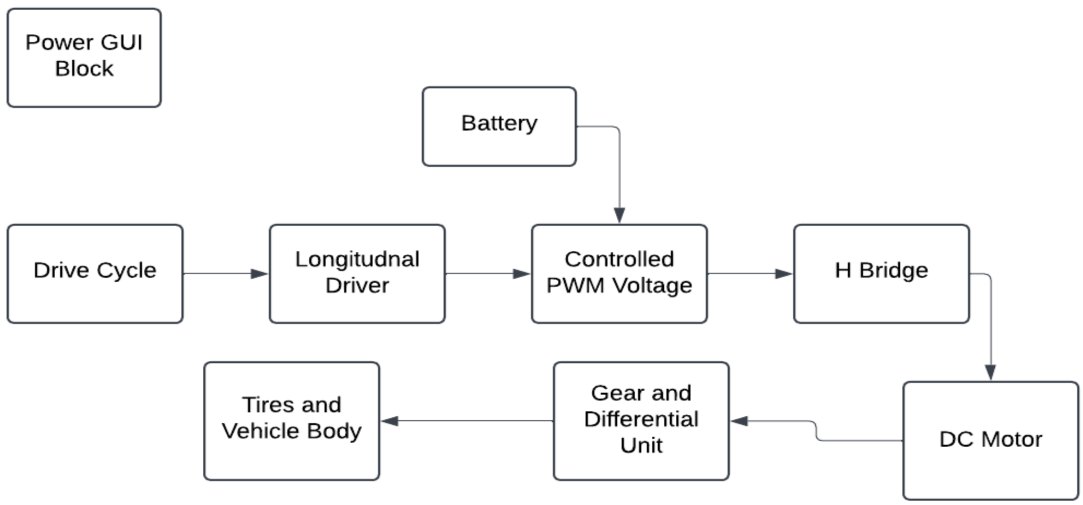


Fig 3.1 Generalized block diagram of Model of E Rickshaw

Vehicle Body

The Simulink Vehicle Body block, available in the Simscape Driveline library, is an essential tool for simulating how forces and torques that act on a vehicle's body will be transmitted. Accurately simulating a vehicle longitudinally taking into account key factors such as mass, aerodynamic forces and slope of the road. Vehicle Body: Computes the vehicle's longitudinal motion considering rolling resistance, aerodynamic drag and traction acting in the x-axis. Block uses the mass of the car as one of its input parameters, which will directly influence the adaptive characteristic acceleration and deceleration.

The block calculates Aerodynamic drag force acting on vehicle by following expression

$$F_{drag} = \frac{1}{2}.\rho.A.C_d.v^2$$

where, F_d = Aerodynamic force

ρ = Air density

A = Frontal area of vehicle

C_d = Drag Coefficient

v = Vehicle speed

The Vehicle Body block is an important Simulink tool for precisely describing and studying the longitudinal dynamics of vehicles, including electric rickshaws, under varied operating situations.

Longitudinal driver

The Longitudinal Driver block in Simulink simulates a driver's input for managing a vehicle's longitudinal motion. It operates as a virtual driver, providing accelerating and braking signals to match the vehicle's speed to a predetermined reference velocity. The block accepts the desired velocity (reference signal) and the actual vehicle speed as inputs, calculates the speed error, and then outputs throttle or brake signals to reduce the error. This capability simulates real-world driving scenarios in which the user controls accelerating or braking based on road conditions and desired speed. The block also works smoothly with drivetrain and vehicle body models, allowing for comprehensive system-level analysis. The Longitudinal Driver block is an important component in vehicle development since it allows for the assessment of energy efficiency, motor performance, and battery use under a variety of operating situations.

H-Bridge

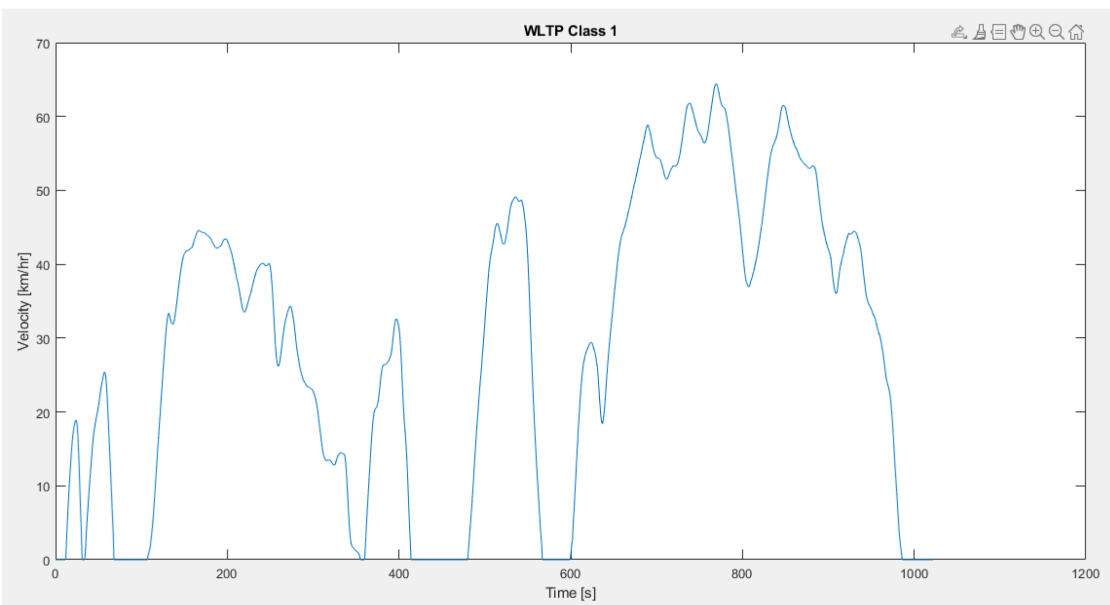
An H-Bridge is an important electrical circuit that controls the direction and speed of DC motors. It is extensively used in electric vehicles, especially electric rickshaws. Its design lets current to flow in both forward and backward directions via the motor, allowing for bidirectional rotation. The H-Bridge is made up of four switches, often transistors or MOSFETs, organized in a way that regulates the flow of current. The circuit alters the direction of the motor's rotation by activating specified pairs of switches, providing precise movement control. Furthermore, the H-Bridge is frequently used with Pulse Width Modulation (PWM) to control the motor's speed by changing the average voltage provided.

Gears and Differential Unit

Gears and the differential unit are critical components in electric rickshaws for effective power transfer and smooth operation. Gears change motor torque and speed, resulting in improved performance on inclines or flat ground. The differential unit lets the wheels to rotate at different speeds during turns, which improves handling and reduces tire wear. These components in electric rickshaws are small and efficient, guaranteeing stability, energy efficiency, and dependable performance in urban and semi-urban settings.

Drive Cycle

A drive cycle is a preset speed-time profile used to assess vehicle performance under real-world driving situations. It simulates a variety of driving conditions, including acceleration, deceleration, cruising, and idling, making it an essential tool for measuring energy consumption, efficiency, and emissions. In this paper analysis was done over two drive cycles WLTP class1 and JC08. Below are details of two drive cycles



- ***WLTP Class 1***

  The WLTP Class 1 Drive Cycle is a standardized driving cycle used for determining fuel economy, energy consumption, and emissions of light-duty vehicles (e.g., Electric rickshaws). The test is intended to more closely replicate real-world driving conditions, particularly urban, suburban and highway driving. The WLTP Class 1 cycle has three phases: low-speed, urban driving; medium-speed suburban driving; and high-speed interstate driving with several acceleration and deceleration events. The cycle consists of four stages — the low-speed urban, medium-speed suburban, high-speed highway and a subsequent extra-high-speed phase that mimics typical driving in towns, down country lanes and on motorways

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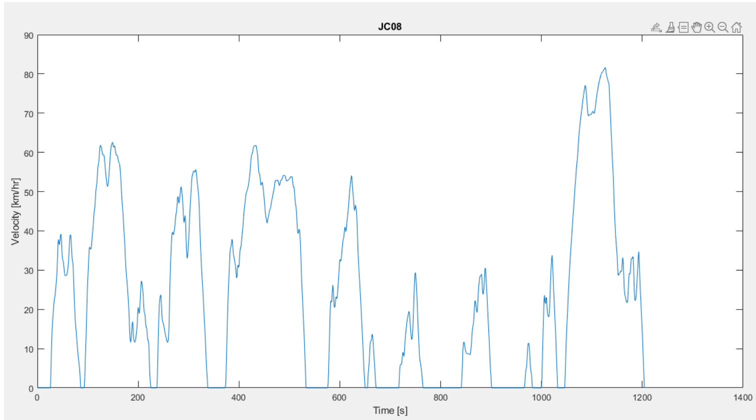
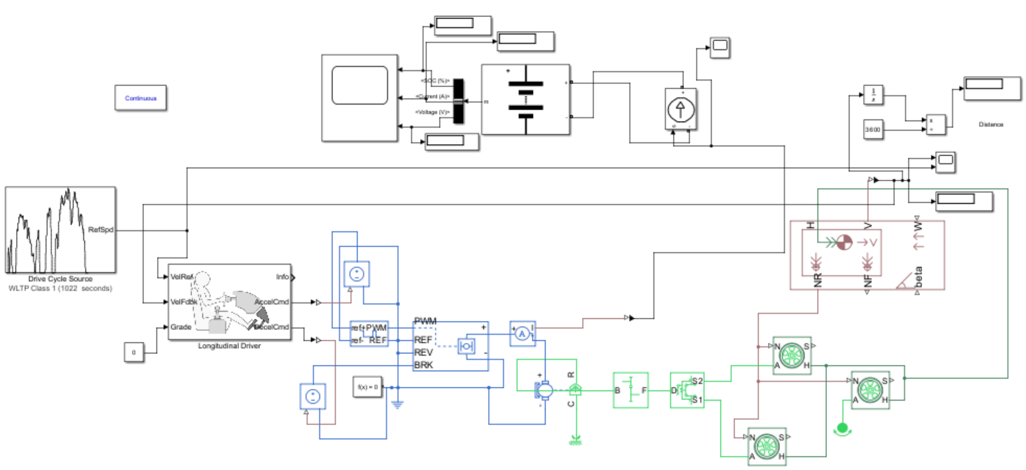


- ***JC08 Drive Cycle***

  The JC08 Drive Cycle is a common driving cycle to be used in Japan for evaluating the fuel consumption, energy utilization and emissions of light duty vehicles like electric vehicles (EV)and hybrids. It is heavily used for automotive testing in the Japanese market. Designed for use on the open roads of urban areas, JC08 replicates typical city and suburb driving conditions, including a great deal of stop-and-go traffic where low speeds and frequent acceleration and braking are the norm. The cycle involves a sequence of driving phases that simulate both city and highway driving. This incorporates low-speed urban driving (think stop-and-go city traffic), moderate-speed suburbia driving, and a section for higher-speed highway cruising

The figure below displays the overall and completed Simulink model, which is made up of several blocks that represent different car components.



4. Software Description

Simulink is a sophisticated graphical programming environment that integrates with MATLAB and is particularly built for modeling, simulating, and analyzing dynamic systems. It is a relatively intuitive block diagram-based interface that allows users to construct complicated system models by linking preset blocks that represent mathematical operations, logic functions, signal routing, and physical system components. For both beginner and experienced engineers, this approach makes it easier to use and more effective by reducing the amount of manual code required. A key component of contemporary engineering workflows, Simulink offers an effective platform for design, simulation, and testing that speeds up innovation and lowers development costs.

5. Results and Analysis

DC motor settings were set in order to examine the E-Rickshaw's performance throughout a range of driving cycles, and the rickshaw's performance was then further adjusted.

Following are parameters considered of standard DC motor

Specifications	Values
No Load Speed	4000 rpm
Rated Speed (Rated Load)	1500 rpm
Mechanical Output Power	40kw

Performance of rickshaw with WLTP Class 1 drive cycle is shown below

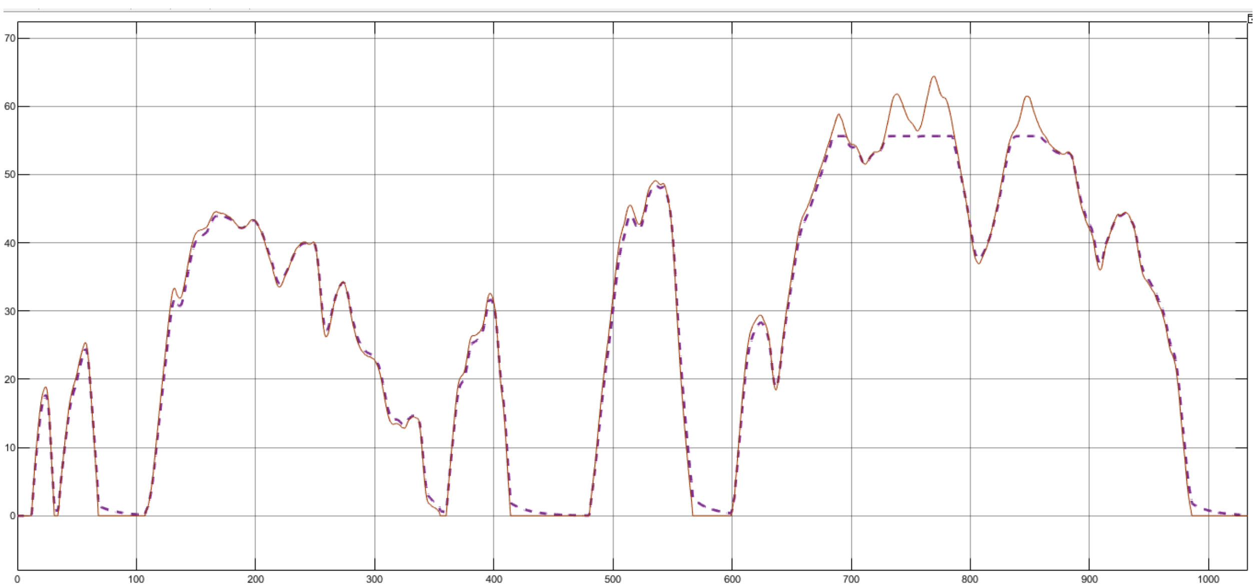


Fig 1: Reference speed and rickshaws speed

In above figure dotted lines shows the rickshaws speed and solid line represents reference speed. It can be observed that vehicle could not reach reference speed, in range of 50 to 60 km/hr.

Below figure represents the Battery SOC, Voltage and current levels when rickshaw was analyzed over above drive cycle.

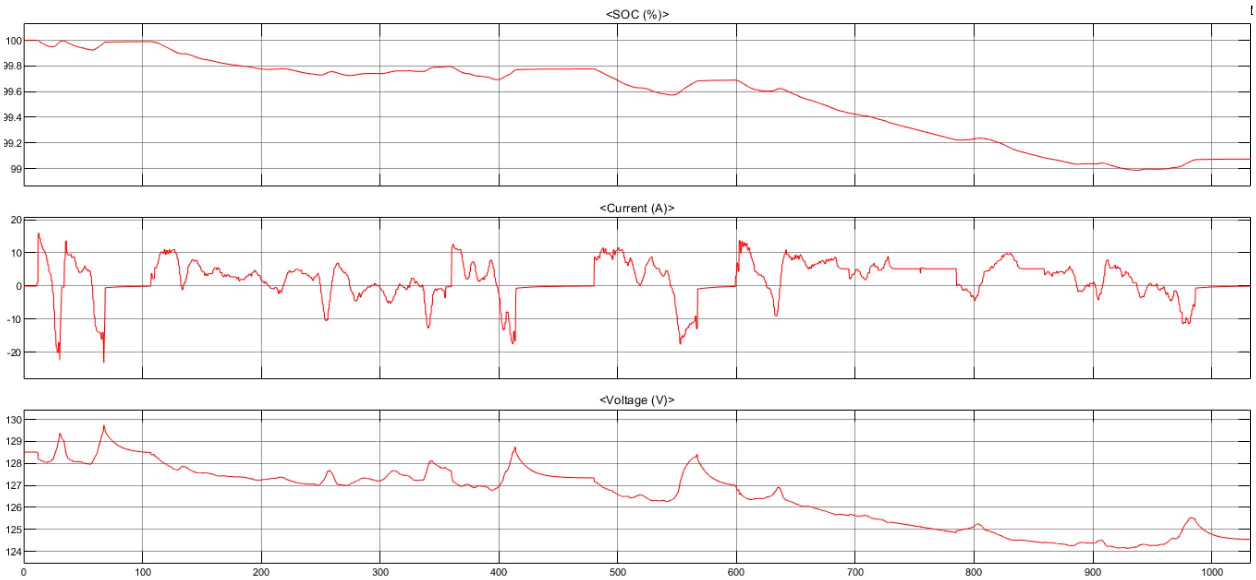
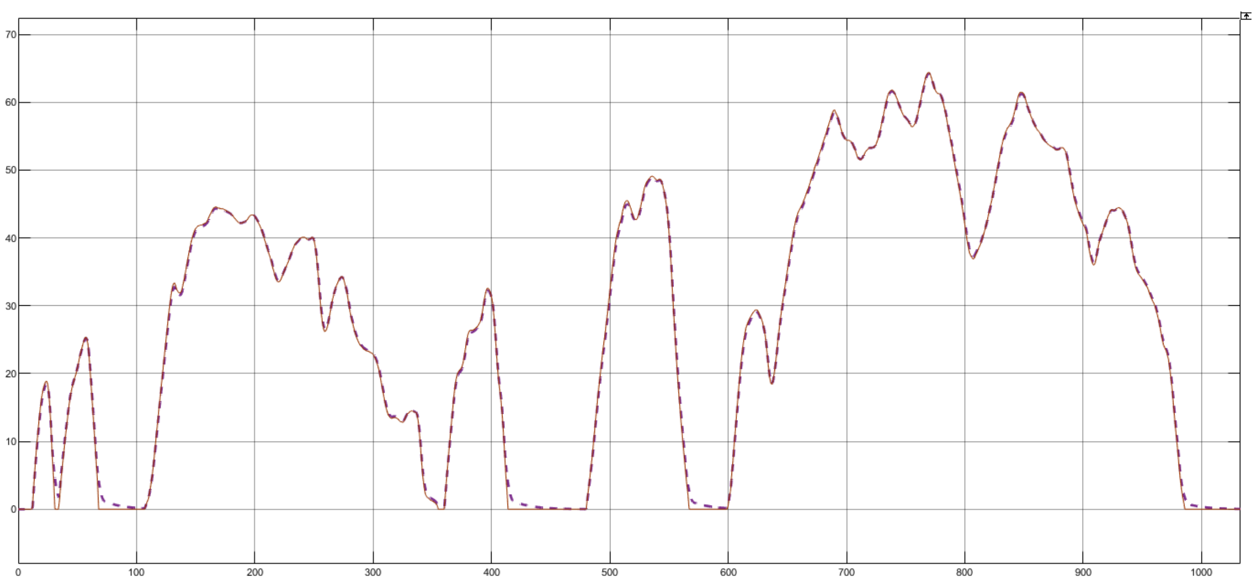


Fig 2: SOC, Current and voltage levels

To improve the performance of rickshaw, no load speed of motor was increased as shown below

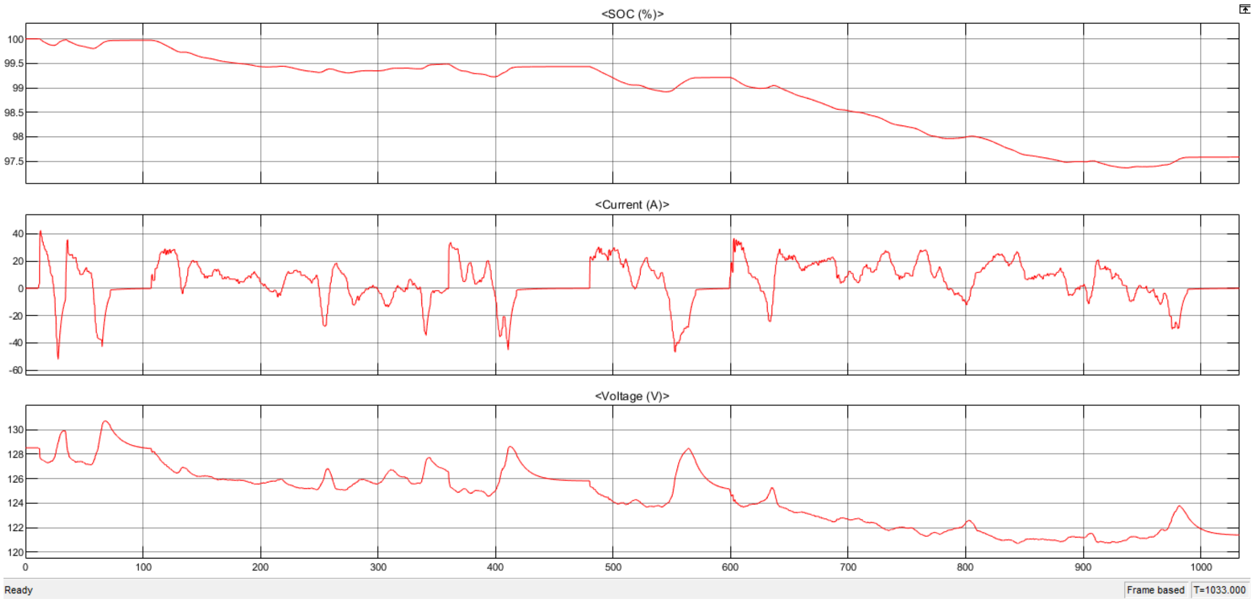
Specifications	Values
No Load Speed	10,000 rpm
Rated Speed (Rated Load)	1500 rpm
Mechanical Output Power	40kw

Following performance was achieved



It can be observed that vehicle speed and reference speed has exactly matched, just by increasing no load speed.

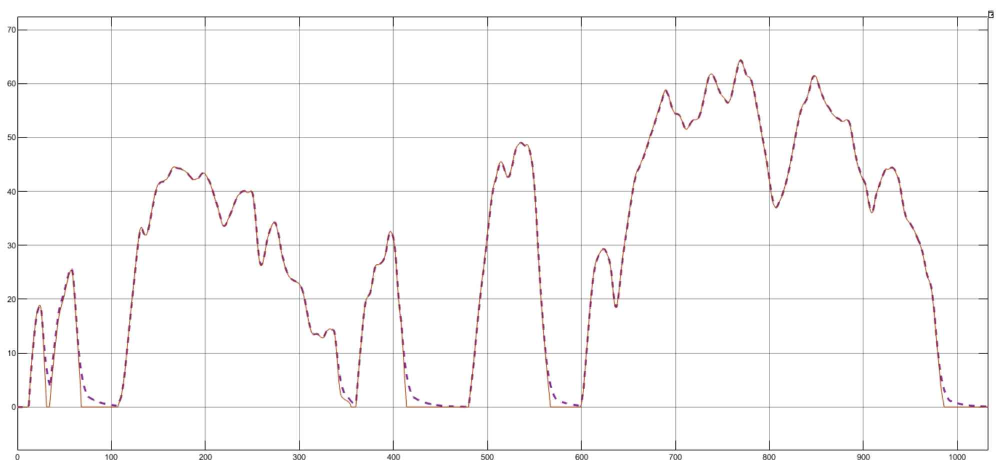
Below figure represents the Battery SOC, Voltage and current levels when rickshaw was analyzed over above drive cycle with varied motor parameters.



Performance was also analyzed with 60kw motor with below parameters

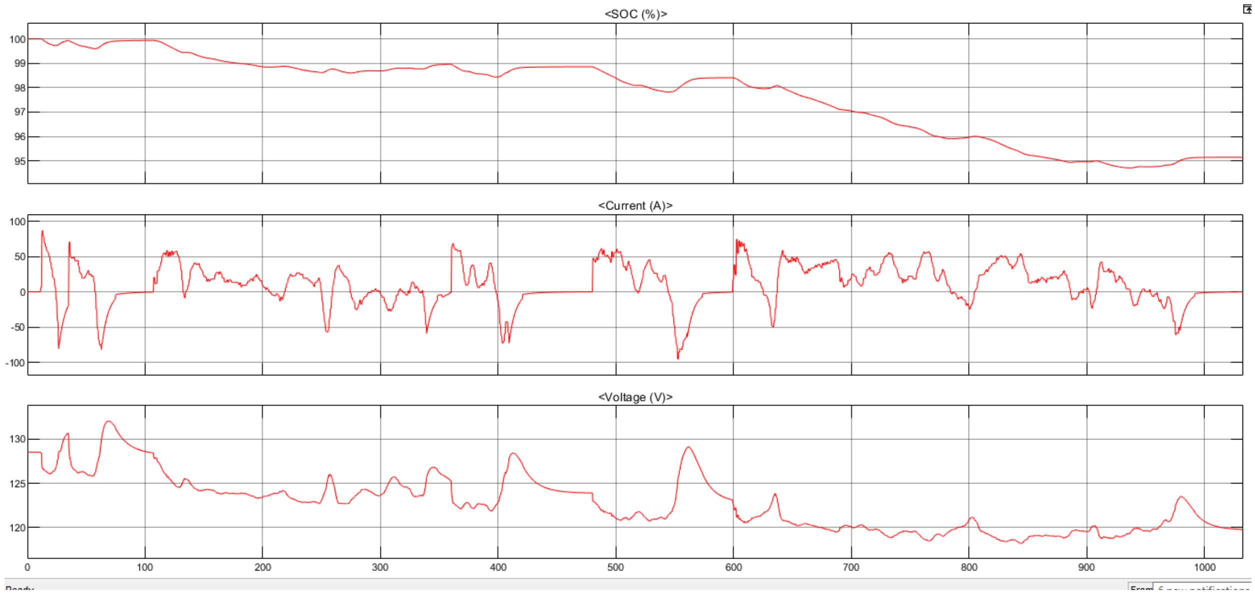
Specifications	Values
No Load Speed	20,000 rpm
Rated Speed (Rated Load)	1500 rpm
Mechanical Output Power	60kw

Following performance was achieved



The vehicle's speed was precisely equal to the reference speed after increasing the dc motor's power and no-load speed further. However, it took a while for the vehicle to stabilize at zero speed during the deacceleration phase because of the high power and high no load speed of the motor. In the case of earlier motor parameter measurements, this was extremely little.

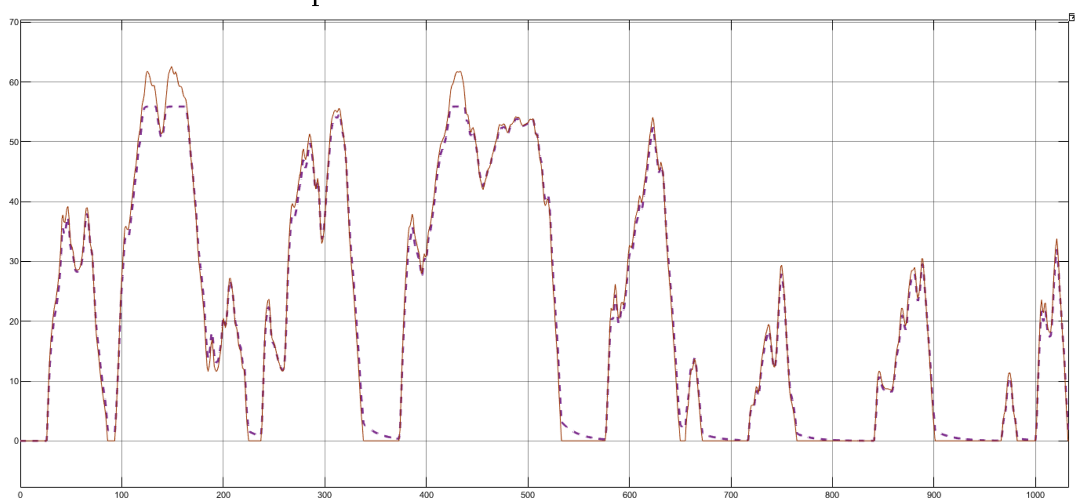
Below figure represents the Battery SOC, Voltage and current levels when rickshaw was analyzed over above drive cycle with varied motor parameters.

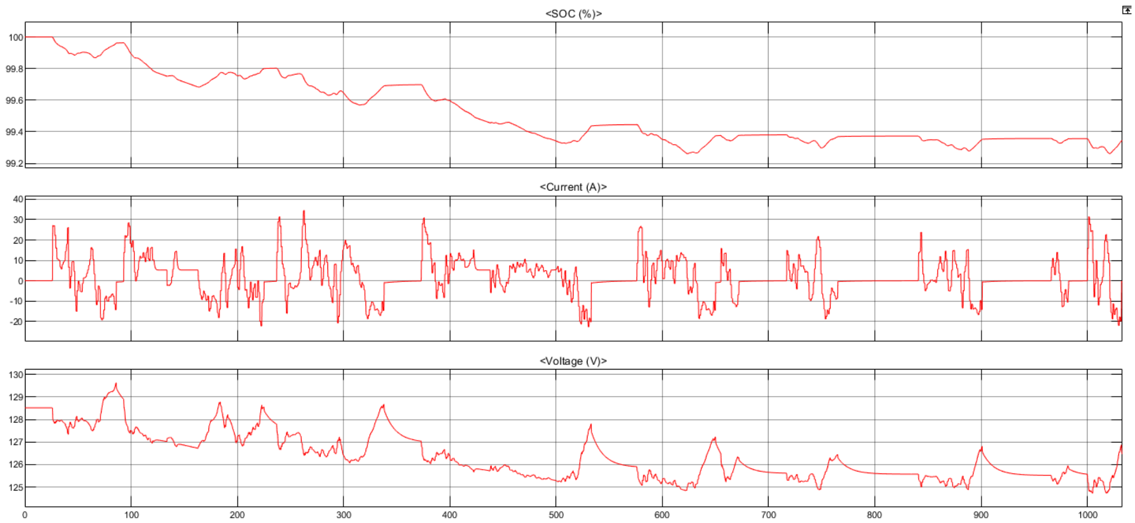


Additionally, it is evident that the SOC % level at the conclusion of the drive cycle has been declining as motor settings have been adjusted.

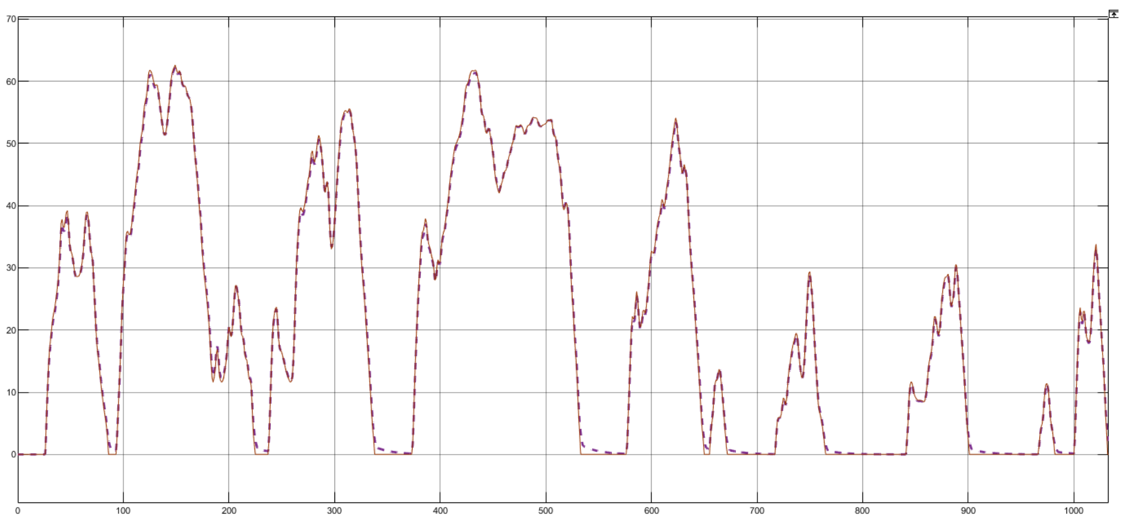
Similarly, analysis was performed over JC08 drive cycle and similar results were observed

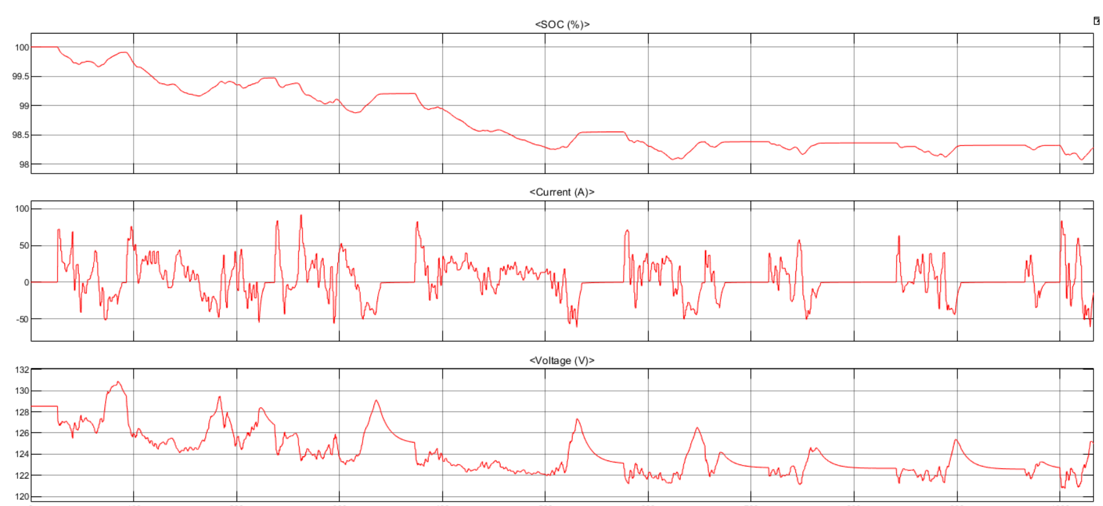
- With standard dc motor parameters



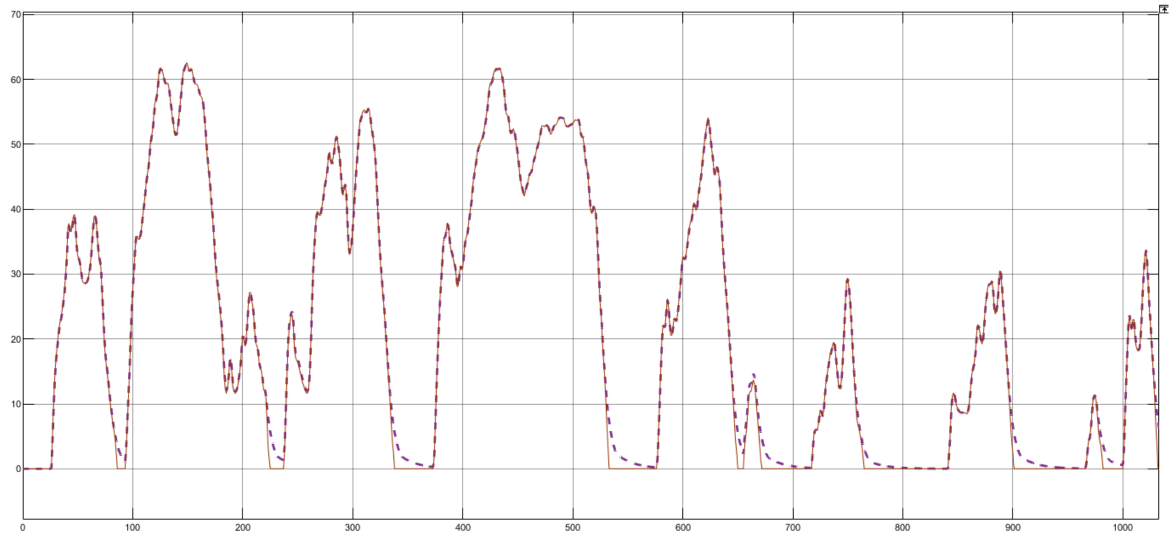


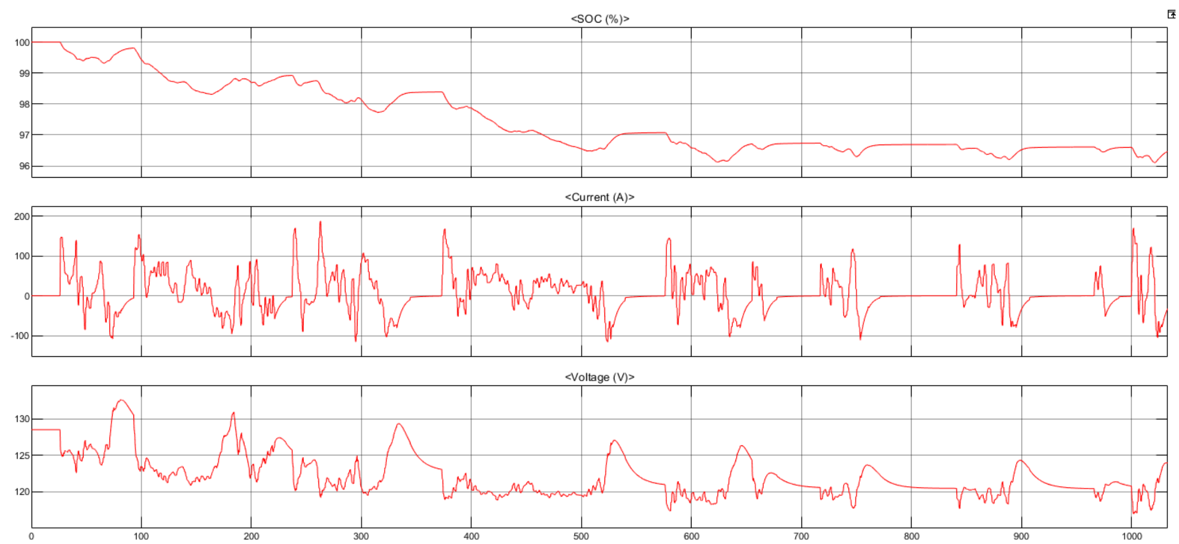
- With 10,000 rpm and 40kw dc motor





- With 60kw motor and 20,000 rpm no load speed





6. Conclusion

The primary goal of this study was to evaluate the performance of an electric rickshaw throughout a variety of driving cycles and motor specifications. It was discovered that vehicle performance is heavily influenced by vehicle specifications; for example, with conventional dc motor parameters, the vehicle could not reach its maximum speed as per drive cycle. However, it became stable toward the apex of the graph. To increase the vehicle's performance, dc motor characteristics were changed, and the drive cycle speed was matched to the vehicle speed. However, as motor parameters were increased, the time it took for the vehicle to decelerate and become stable increased; hence, the right motor configuration must be chosen to accomplish the vehicle's desired performance. In electric vehicles currently in the market, simple standard dc motors are not employed. it does not give required performance. From this project it can be concluded that specially design motors with proper configurations are used for efficient and correct results. Also, battery's SOC, Current and Voltage was observed as parameters of motor were varied.

7. References

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