Design of E-Rickshaw Using Matlab or Simulation

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***Abstract*— Changes in electricity supply to conventional vehicles due to rising fuel prices and environmental concerns have also affected three-wheeled vehicles. Three wheeled vehicles, known as Auto-rickshaws, are the most common form of transportation in India. Existing battery powered rickshaws (known as E-rickshaws) found in major cities of India face challenges such as insufficient charging points, low driving distance, high battery costs, battery replacement / disposal, etc. Battery-ultra capacitor (UC) mixed power. a source is suggested in this paper to overcome these problems. Dual power sources with compatible features, when used in conjunction, can improve overall car performance in terms of weight, volume, and efficiency. An E-rickshaw with mixed- power batteries-UC is modeled on MATLAB-Simulink in this paper. A very logical and unconventional approach to power management was used between the two sources through the efficient use of renewable energy generated during braking. The system was later tested in the Real-Time Hardware-in- Loop (HIL) area to verify the simulation results. It has been observed that the addition of an additional source with compatible features has improved the performance of the vehicle.**

Index Terms: **Battery-Ultra capacitor, Electric Vehicles Energy Management, Fuzzy Logic, Regenerative Braking etc.**

I.INTRODUCTION

India, which has the second largest population in the world [1], is also home to some of the world's most polluted cities [2]. Fourteen of the 20 most polluted cities in the world of India according to a recent study based on PM2: 5 particulate matter [3]. A major contributor to pollution in these cities is the emission of motor vehicles [4]. 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. Three-wheeled vehicles is called Auto-rickshaws, play a vital role in public transport in India as well as trains and buses. Unlike the other two, self- propelled rickshaws are chosen for shorter travel distances (preferably within cities) because of their compact size. The city of Tier-I (with a population of over 4XXX-X-XXXX-XXXX- X/XX/$XX.00 ©20XX IEE million) occupies more than 50,000 [5] car rickshaws in India. That can be up to 4-5% or sometimes up to 10% of the city's traffic population. These vehicles can be a major source of air pollution and are also a major customer of petroleum resources [6]. 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. In this paper the conversion of the E-rickshaw vehicle is modeled on Matlab-Simulink.

II.VEHICLE DYNAMICS OF AN E-RICKSHAW

The typical rickshaw structure is shown in Figure 2. The details of the default rickshaw are shown in Table 1 [12] whose parameters are considered as the reference for designing an E-rickshaw power train.

Table 1: Specifications of Conventional Auto-rickshaw

Specifications	Values
Gross vehicle weight, M	610 Kg
Kerb weight	272 Kg
Tyres, r_w	4.00-8, 4PR
Roll resistance, C_r	0.015
Air drag coefficient, C_d	0.44
Frontal surface area, A_f	2.0 m^2

The load capacity is calculated based on the driving cycle and vehicle capacity. Energy source measurements are made based on this energy requirement.

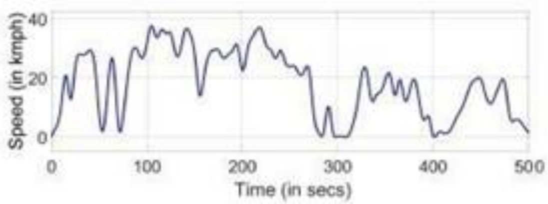
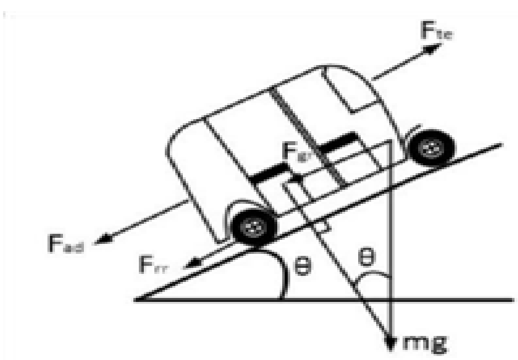


Figure 1: Indian City Drive Cycle (IDC)

The driving cycle is calculated and selected because the Erickshaw is intended for use in cities. The charging power requirement is calculated in the typical driving cycle of an Indian city shown in Figure 1. The battery and ultra capacitor had a size based on these power requirements. The flexible modeling of the vehicles is described in detail in the following sections.

1)Total Tractive force

The operating force of a car needs to be understood in order to have an effective model of car dynamics. The power of the auto-rickshaw rickshaw as you climb the hill is shown in Figure 2. The gravitational force produced by a car's electric motor must meet and overcome these forces namely (a) Rolling resistance (b) Aerodynamic gravity (c) Distance resistance and (d) acceleration capacity.



The maximum force applied to the E-rickshaw and its meanings are shown in Table 2. Here, M is the weight of the vehicle in kg, g is the gravitational constant, i.e., 9.81 m = s2, Cr is the coefficient of rolling resistance. E a road with a horizontal plain and aa speeding vehicle for m = s2. The sum of the force of gravity is the force required to propel the car forward by overcoming all the aforementioned forces operating on the vehicle. Ignoring all other power directly or indirectly in the vehicle, the full operating power can be found in Eq 1.

Fte= Frr+ Fad + Fgr+ Fa f (1)

III.E-RICKSHAW SYSTEM ARCHITECTURE

Evaluation of all components such as power source, electric motor, power converters etc., E-car charts depends on car parameters and driving patterns. The total amount of traction the vehicle needs to drive is calculated using Eq.1. System parameters such as vehicle weight, front position etc., are found in Table 1. Vehicle speed and acceleration are found in the driving cycle data. The required load capacity is calculated as a product of total gravity and speed.

The power flow in the standard electric rickshaw is as shown in Figure 3. The dynamics of the automatic rickshaw are modeled in the Matlab-Simulink area.

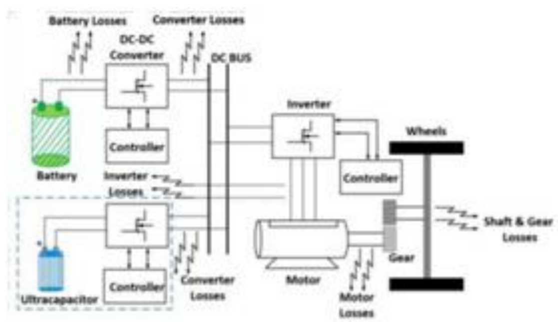


Figure 3: Energy flow diagram of E-rickshaw

The E-rickshaw is designed for the Indian Drive Cycle (IDC) measuring a total of 500 seconds. The car, which operates in cities, aims to travel at a speed of not more than 40 km / h due to the constant start and stopping of vehicles. The top speed is considered to be close to 38 km / h

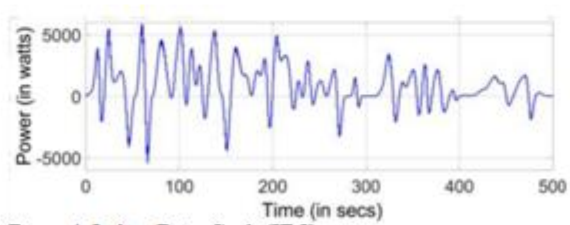


Figure 4: Indian Drive Cycle (IDC)

The load capacity of the Indian City Drive Cycle (IDC) is shown in Figure 4. The maximum power requirement was found to be approximately 5.0 kW. Assuming that the constant source voltage is 48V (most E-rickshaws in India are powered by a 48V Lead acid battery).

The proposed E-rickshaw is expected to have a driving distance of 75 kms and the total distance traveled per day is expected to be 150 kms, at which point by charging twice a day. Typical charging time is 2.5-3 hours. Figure 6 (a) shows the average speed at which an E-rickshaw travels through the city. The vehicle covers a distance of 2.548 kms at the end of 500 seconds (Figure 6 (b)) with an average speed of 18.3 kmph.

Table 2: Forces Acting on an E-rickshaw

Force	Definition	Expression
Rolling Resistance force, F_{rr}	The force experienced by the vehicle due to friction between the tyres and the running surface.	$C_r.M.g$
Aerodynamic drag, F_{ad}	The force experienced by the vehicle due to friction with the surrounding air.	$\frac{1}{2}\rho.A.C_d.V^2$
Grade Resistance force, F_{gr}	The force required to drive the vehicle upward on a slope.	$M.g.Sin\theta$
Acceleration force, F_{af}	The force which is needed to accelerate the vehicle for different running velocities.	$M.a$

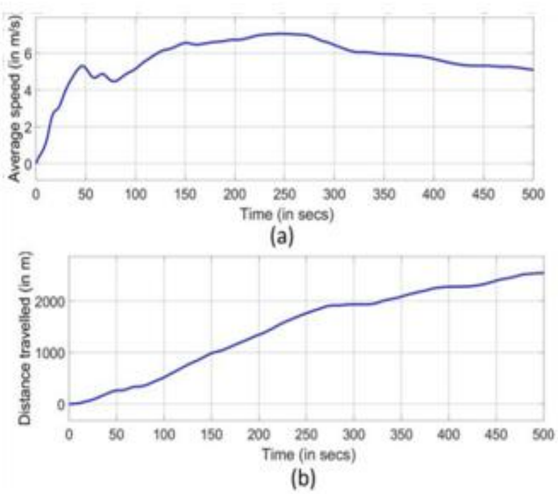


Figure 6: (a) Average Speed of an E-rickshaw (b) Total Distance travelled at the end of 500 secs

IV.SIMULATION RESULTS

The vehicle was tested in the Matlab-Simulink area for various battery and ultra capacitor conditions. The results are discussed in detail below.

Case-I: Battery and Ultra Capacitor fully charged

Both the battery and the ultra capacitor are considered to be fully charged initially (i.e., Initial SOC = 100%). Depending on the power requirement, SOC battery and ultra capacitor SOC, the load capacity is shared between the battery and the ultra capacitor as shown in Figure 10.

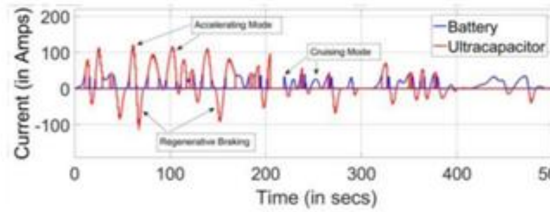


Figure 10: Case-I: Power split Battery

It is clear that during the sailing mode the battery provides the required power even during the high power requirement (acceleration mode) and while the regenerative braking ultra capacitor provides / absorbs power respectively. The charging status (SOC) of the battery and ultra capacitor is shown in Figure 11.

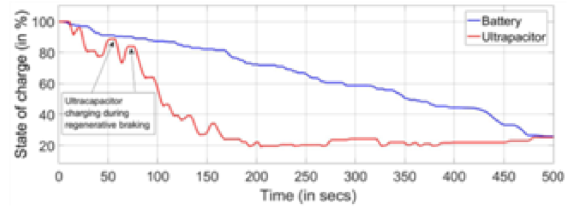


Figure 11: Case-I: Battery and Ultra capacitor comparison

The terminal characteristics (VT) of the battery and ultra capacitor when using the Indian drive circuit are shown in Figure 12.

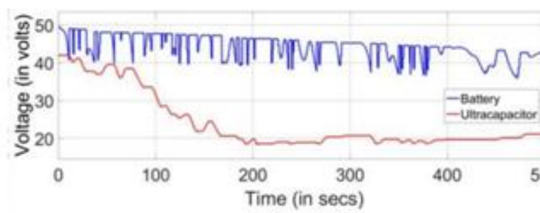


Figure 12: Case-I: Battery and Ultra capacitor Voltage

The car is capable of operating on all three modes of driving namely, sailing, acceleration and re-braking. During the refurbishment of the brakes the ultra capacitor is charged as shown in Figure 11. The battery is able to provide much longer power when connected to the ultra capacitor compared to operating alone thus improving its health. The Ultra capacitor effectively absorbed the energy produced during braking thus improving vehicle performance and energy efficiency.

Case-II: Battery fully charged but UC less charged (Batt- SOC=100% & UC-SOC=25%)

The battery is thought to be fully charged at the beginning (i.e., Original SOC = 100%) and the ultracapacitor is considered to be 75% discharge.

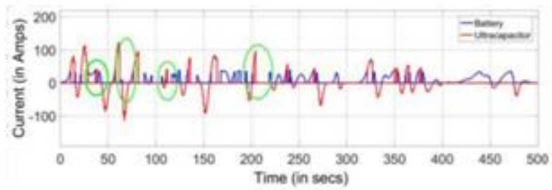


Figure 13: Case-II: Battery and Ultra Capacitor power split

Depending on the power requirement, the SOC battery and the ultracapacitor SOC, the load capacity is shared between the battery and the ultracapacitor as shown in Figure 13 of the standard Indian drive (IDC) cycle. During sailing the battery provides the required power but during high power (acceleration mode) the ultracapacitor is not available to meet system requirements when its SOC level has reached less than 20% (see highlighted areas in Figure 13). During regenerative braking, the ultracapacitor pulls the energy used later to meet the car's needs while speeding up the process. The charging status (SOC) of the battery and the ultracapacitor are shown in Figure 14.

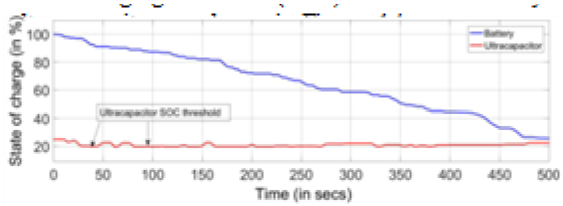


Figure 14: Case-II: Battery and UC comparison

The terminal characteristics (VT) of the battery and ultra capacitor are shown in Figure 15. Since the ultra capacitor is already 75% disconnected, its terminal voltage will be 24V, as the output depth will be 75% ultra capacitor. while the terminal voltage drops by half.

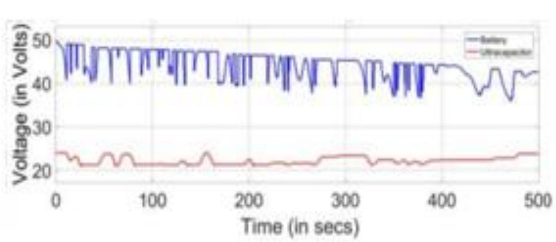


Figure 15: Case-II: Battery and UC Voltage (VT) comparison

V.IMPLEMENTATION RESULTS

The proposed ambiguous power separation between the battery and the ultra capacitor was tested by testing in the laboratory environment using the Xilinx board made of Spartan3 FPGA (XC3S5000). Two Agilent make DSOX2002A channels are used to record real-time performance. The Indian city drive cycle generated from real limited data is re-created in the lab and shown in Figure 19.

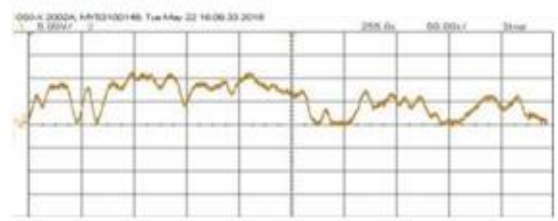


Figure 19: Real-time Indian City Drive Cycle at laboratory environment the current will be taken from the power source to meet the vehicle requirements as shown in Figure 20.

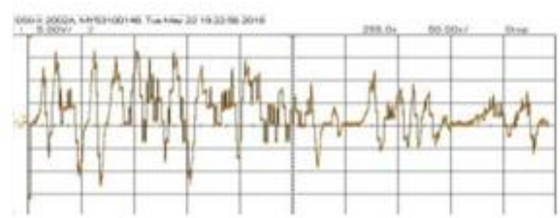


Figure 20: Source current requirement of E-rickshaw

The Matlab-Simulink model car has been successfully redesigned in a real-time environment. The currents taken from the energy source in the various types of vehicle operations have been shown to be closely related to the effects of simulation. All three battery-based vehicle and ultracapacitor state of charge (SOC) vehicle tests were pretested and Matlab-Simulink tested in the laboratory. The results were found to be similar and are briefly discussed below.

5.1 Case-I: Both Battery and UC fully charged (Batt-SOC=100% & UC-SOC=100%)

Both the battery and the ultracapacitor are fully charged. As shown earlier, the car is capable of operating on all three modes of driving namely, cruise, acceleration and regenerative braking. Ultracapacitor is charged during the re- braking as shown in Figure 21.

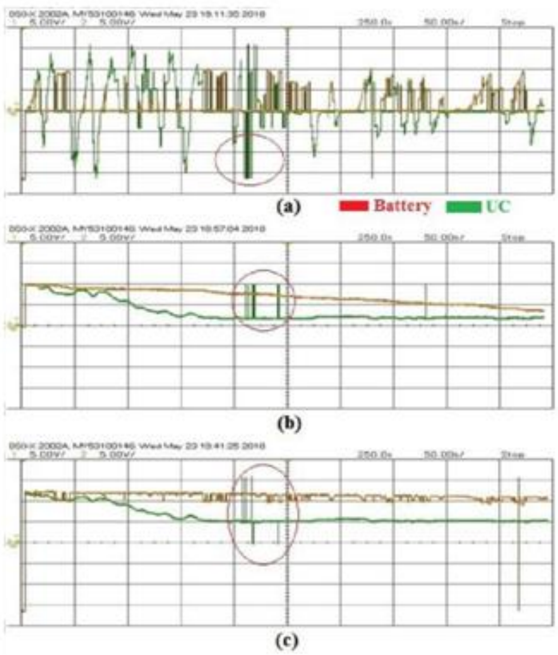


Figure 21: Case-I: Battery and UC

VI.DISCUSSION AND CONCLUSION

Rickshaws, or even though they are a common means of transportation, are under very little research to improve their performance. Conventional E-rickshaws use the same limited power source for driving distance. In the case of India, the success of E-rickshaws will always be measured by driving distance and cost. It is envisaged that combining a high-power device (UC) to share high power demand with a conventional power supply (battery) will improve the performance of a vehicle that has never been tested on E-rickshaws. Improved SOC and terminal voltage features can increase E-rickshaw driving distance. And since UC is able to meet high power requirements, the battery can be measured at a much lower average current requirement. This will greatly reduce the size and cost of the car. Since a battery in a standard e-rickshaw takes up about 15-20% of its edge weight, any weight loss and battery size per minute will always result in better performance. The UC also has faster charging / discharging features than batteries that can be used to absorb renewable energy during downtime and better braking. This paper attempted to consolidate the energy sources for the construction of the E-rickshaw system in the Indian state. Performance improvements were developed using simulation and application in real-time results in this paper. Successful implementation of an intuitive power management algorithm has improved E-rickshaw performance. Vehicle power is calculated in real time based on the driving cycle of an Indian city calculated Cars tested three different driving modes and three battery charging conditions with ultra capacitor. It was found that the algorithm was very efficient with minimal IX. calculation and complexity. The use of E-rickshaw mixed power source can extend its driving range. And the effective absorption of the generated renewable energy can improve vehicle performance.

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