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A Dynamic Model for the Performance Analysis of an Innovative E-Bike Using Supercapacitors.

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Abstract: *The paper describes fabrication of an E bike and its performance analysis by means of a dynamic model equipped with a suitable control for the management of the assisted drive of the e-bike. The main advantage of this approach consists of the opportunity to simulate different versions of performances, e-bikes characterized by different parameters (total mass, motor torque, top speeds under different load conditions) and different control strategies. The study also undertakes comparison of the e-bike with a regular e-bike. A test setup to see the difference between an e-bike with only assistance of a li-ion battery package and the second with the assistance of a li-ion battery pack along with supercapacitors. The basic approach to this study is to confirm the fact that the li-ion battery performance and range can be improved with the combination of super capacitors.*
Keywords: *e-bike, li-ion batteries, super/ultra capacitors, lead acid battery, vrla, ECU, 3phase, safety, sustainability.*

I. Introduction

Strong problems related both to the air quality and to the use of petroleum have been caused, in the recent years, by the increasingly vehicular traffic. Particularly, the most of consumption and pollution are attributable to the great mass of the vehicle and not to the mass of the handled passengers. Under this point of view, a vehicle as the electrical assisted bicycle (e-bike) or an electric powered bike can be considered a promising alternative vehicle for both personal mobility goods delivery, especially for small and medium distances.

The e-bikes are normally powered by rechargeable battery, and their driving performance is influenced by battery capacity, motor power, road types, operation weight, control, and particularly the management of assisted power. A classification of these BEVs (battery electric vehicles) is necessary. A first kind is represented by a pure electric bike, which integrates electric motor into bicycle frame or wheels, and it is driven by motor force only using a handlebar throttle. A second kind is a power-assisted bicycle, frequently called e-bike or pedelec, which is a human–electric hybrid bicycle that supports the rider with electric power only when the rider is pedaling.A number of possibilities favor the use of electric bicycles in different situations. These include lower energy cost per distance travelled for a single rider; savings in other costs such as licenses, parking; improvement of the traffic flow; environmental friendliness; and the health benefit for the rider.

This paper presents the performance of an innovative electric bicycle by means of a dynamic model equipped with a suitable control for the management of the assisted power. The applied approach gives us an insight on how the performance of an electric with a li-ion battery differs from an electric bike assisted with a li-ion battery in parallel with a super capacitor bank.Provide an economical solution for the masses by producing a low cost e-bike prototypeUsing Li-ion batteries and super/ultra capacitors together to provide efficient power for the motor and hereby extend the travel range of the e-vehicle. Brake regenerative system will help in extending the range of travel by sending energy back to the capacitor bank rather than to the batteries.

II. Methods And Methodology

The objective of this test setup is to show the application of li-ion batteries(or any other standard battery) operating along with super/ultra capacitors in order to improve the efficiency of travel range and also the shelf life of the battery in use.

For any standard vehicle, the load on the engine is at maximum when the automobile starts from rest. Similar to this the load on the motor is highest when the automobile is starting from rest. Heavy load demands for high current draw from the battery pack which can cause damage to battery cells due to high discharge rate. This phenomenon can be counteracted by use of super/ultra capacitors. Super capacitors have the ability to accept and discharge extremely high amounts of energy in a very short span of time without heating up as compared to batteries.

Brake regenerative systems can be applied to this system where rather than sending charge back to the battery pack we send it to the capacitor bank instead since they accept charge faster than batteries. Batteries tend to heat up while accepting charge due to high internal resistance.

This can be acquired by using switching circuits between the battery bank and the capacitor bank to jump between each of them as and when they are required.

The electric bike prototype

The dynamic model adopted for the numerical analysis refers, in terms of the adopted parameters, to an innovative e-bike that will be briefly recalled in this section. The innovative prototype is based on the following solutions:

- the electrical motor location;
- the battery pack located into the frame;
- the mechanical transmission;
- The low cost measurement system of the driving torque.

In our setup the electric motor is located below the crank pedal of the bicycle. As shown in Fig. 1, a second chain supporting sprocket is fitted above the motor on the central cycle body hubs.

1. Project components

- Vehicle chassis.
- A.C. Electric motor (3-phase)
- A.C. Motor driver system [motor controller]
- Battery block[Li-ion battery] 48v 10Ah
- Super/ultra capacitors
- Brake regenerative system
- B.M.S. [Battery Management System]
  - Includes constant voltage, constant current function to charge batteries to the specified voltage and capacity as prescribed by the manufacturer.
  - Safety cut-off system after full charge/low voltage/surge voltage protection.

Fig: 1. Vehicle chassis

Fig: 2. Electric motor

Fig: 3. Motor controller

Fig: 4. Battery and supercapacitors

Comparison of battery technology

Table 1: Differences between valves regulated lead acid (VRLA) batteries and li-ion batteries.

Valve regulated lead acid battery	*li-ion battery*
• Heavy and bulky. • Low cycle life(200-300 cycles) • Comparatively safer to use as compared to other high energy density batteries since they can take surge voltages and electrical abuse. • Low power capacity to size ratio.	• Small in size, more compact. • High life cycle (800-1200 cycles) • Batteries do not accept abuse such as impacts, over-voltage, over-charge, over-discharge. • High power capacity to size ratio.

Table 2: Comparison between battery and supercapacitors

Battery	***Super capacitor/ ultra capacitor***
• Recharging and discharging requires time. • Stores high density of charge for a long time • Cycle life is short • Do not accept abuse (over-voltage, over-charge, over-discharge, surge) or mechanical impacts. • High internal resistance(limits the output current for the battery)	• Recharging and discharging takes place almost instantly. • Stores high energy density for a long time but can discharge it at a extremely high rate. • High cycle life (about 100,000 cycles) • Extra voltage is stored as instantaneous reusable energy. • **Extremely** Low internal resistance

Reasons of using super/ultra capacitors

- Standard batteries are till date not suitable for high discharge and fast recharge rates of current required by the motor drive system as this deteriorates the life cycle or useful life of a battery at a faster rate.
- In order to counteract this situation, super/ultra capacitors step in. These charge up quickly and can be discharged quickly without any harm caused to themselves or the batteries.
- During the starting phases of moving the body from rest, a high torque is required by the motor which is basically high demand for current in the range of 50 to 100 amps, but only for a short span of time.
- Ultra capacitors can be easily recharged by using break regenerative system as they require minimum time to recharge.
- During acceleration from rest, the batteries can be cut-off until the vehicle acquires a range where less current is required.

SWOT analysis

Table 3: SWOT Analysis

• **Strength**- reduced cost due to Use of less equipment (by Using supercapacitors Which are cheaper then batteries and can store and provide high discharge current as and when needed by the motor) • Using supercapacitors Increases the cycle life of the Batteries as there will be less Load on them. • Increased safety due to speed Limit.	• **Weakness:** only applicable for small and medium distance travel • possible to carry limited to weight due to reasons such as battery capacity, motor capacity • li-ion batteries require a sustainable BMS system which will provide longevity for their useful life • li-ion batteries are expensive due to rare earth matters used such as nickel and cobalt

Table 4: Technical specifications of the e-bike.

Frame	14kg
Motor	5 kg
li-ion Battery pack	2.7kg
Motor driver module	0.227kg
Super capacitor module	0.850kg
Tyre (per tyre)	2.9kg
Total weight	28.577kg

Fig 5: Chain and sprocket system

Fig 6: Chain drive system

III. Discussion And Testing

Sr.No	Lap	Time Elapsed	Time Difference (min)
1.	1	12:28-12:39	11
2.	2	12:39-12:51	12
3.	3	12:51-13.08	17
4.	4	13:08-13:20	12
5.	5	13:21-13:33	12
6.	6	13:39-13:53	14
7.	7	13:56-14:19	14
		Average:	13m 14s

The following test was conducted under the following standard conditions:

- Battery voltage at full charge=**51.9volts**
- Battery voltage after final lap=**45.2volts**
- Difference in voltage=**6.7volts**
- ECU voltage cutoff=**44volts**
- Highest value of current draw from motor=**16.32 Amps**
- ECU idling current (motor in dormant condition)=**20mA**
- Current readings were taken by setting a test rig along with the setup by using a multi-meter with current reading functions. The average current reading obtained after the test under body load of **28.58 kg** and the test subject weighs **63 kg** the total summing up to **91.58 kg** is=**4.1A**
- Each lap has an average distance of **4.4km** (the test was conducted with no incline and declines. Total distance covered till voltage drop of **45.2 volts** =**30.8 km** (theoretically, ignoring slight deviations in travel paths by a factor of **1-2%.**
- Average speed calculated from the test rig is at **23kmph.**

IV. Conclusion

The following setup has helped us to better understand the applied concepts of e-bikes and their promising applications in the near future.

This report has described the environmental analysis of an electrically assisted bicycle under real driving conditions of simulated speed-time profiles. In this study, experimental results of measurements performed on a thermal moped were employed in order to collect the data during real driving conditions. The environmental assessment was performed taking into account a comparison with the emissive behavior of this moped by using kinematic parameters that describe the simulated driving dynamics; a clear benefit of e-bike compared to thermal mopeds was shown and quantified in terms of emissions saved of CO, HC and NOx.

In these conditions, it has been possible to measure the performance of the e-bike in terms of instantaneous power and speed versus distance, by the installed sensors and data acquisition system. The experimental results have allowed comparing the total energy and the electric one for both the tracks. This study has provided several results and guidelines that can assist for such improvements in the performance of electric bicycles. Future developments will improvise on the following in the years to come.

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