Pedagogical study of an electric bike with low energy consumption, management and dimensioning of onboard energy : eco marathon

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Abstract: - The electric bike is a very good educational system because it can be used by all students without problem of safety. When pedaling on the electric bike, the student can identify with the motor drive and understand the meaning of torque, speed and power. This educational system uses many modules of Electrical Engineering: power converter, battery, motor, controller, electronics, lights, instrumentation, sensors, mathematical modeling, mechanics...
Thus, many technologies can be presented. These vehicles have a difficult compromise between weight, power, battery life, and price. These vehicles could be implemented using new composite materials and new Lithium batteries. But to increase the lifespan of the batteries, which represent 35 % of the electric vehicle price, we will demonstrate the benefits of a control with constant power through the motor, compared to a control with a constant force. This paper will outline the resistive power, as a function of vehicle speed and the state of energy consumption. A comparison of energy prices between different kinds of electric vehicle will be presented. The advantages and disadvantages of using super capacitors will be presented, as well as energy management on board the motor speed controller. Then, an overview of the regulation of a fast charger with current control and voltage control will be presented. Finally, many educational applications will be presented around the electric vehicle realized.

Key-Words - Challenge Eco Marathon, motor control constant power, Lithium battery, motorized electrical cycle, project-based teaching, battery charger, super capacity, energy management.

1 INTRODUCTION

Vehicles with low electric power consumption [1, 2, 3, 4] are becoming new actors for transport in our congested cities. This type of vehicle meets the demand of minimizing the production of CO2 and responds also to the future energy transitions.
We will see that it is possible to build vehicles traveling at 80 km/h maximum with a engine power of less than 4000 W. We will see that the energy consumption can reach a value of 560 Wh/100km at an average speed of 50 km/h, with a autonomy of 180km, so a consumption of 1600 km with the equivalent of a liter of petrol.
The electric bike is a very good educational system because it can be used by all students without problem of safety. When pedaling, the student can identify with the motor drive and understand the meaning of torque, speed and power. This educational system uses many modules of Electrical Engineering: power converters, battery, motor, controllers, electronics, lights, instrumentation, sensor, mathematical modeling, mechanics...

We will now define the vehicle mathematically to understand its characteristics (maximum speed, size, acceleration...). For the sake of simplicity, we will not go into detail regarding the mechanical losses of the engine, the control (speed control and/or current), the power electronics...
Firstly, we will briefly present the resistant power as a function of the vehicle speed and then present the dimensioning of the vehicle, the control of electric motors and finally the cost of this transportation way.

2 FORCE AND RESITIVE POWER AT A FIXED SPEED

The resistive force [5] depends on the rolling resistance, the gradient of the road and air resistance. Their respective equations are:

$$F_{resistive}(N) = F_{Rolling} + F_{slope} + F_{Air} \quad (1)$$

$$F_{Slope}(N) = M(kg) \cdot g \cdot Slope(\%) \quad (2)$$

$$F_{Air}(N) = f_{air} \cdot [S(m/s) + S_{wind}]^2 = \frac{1}{2} \cdot \rho \cdot S \cdot Cx \cdot (S + S_{wind})^2$$