Electric Bicycle design using PMDC Drive

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Abstract - Electric Bicycles have been gaining attention as an efficient and clean means of transportation. This paper focuses on the design and implementation of a hybrid powered electric bicycle employing a dc-dc power converter. Two DC sources are used: battery and super capacitor. The super capacitor is connected in parallel to the battery and a dc-dc converter is designed in closed loop which arbitrates power between the battery and super capacitor. The purpose of employing super capacitor is to drive the vehicle during the peak power required by the load. The main components of the proposed electric bicycle are: battery, super capacitors, dc-dc converter, controller and PMDC motor.

Index Terms- Electric bicycle, ripple, duty cycle, state of charge

INTRODUCTION

In the present era, there is an increasing demand for transportationfor which is safe and cheaper and it reduces the air the pollution. Therefore, the use of electric bicycles has increased. Conventionally, dc motors are employed but it suffers from commutation problem and requires frequent maintenance. The deployment of Brushless DC motor (PMDC) for e-cycle overcomes the above problem. The PMDC motor is electrically commutated by power switches instead of brushes and is highly reliable since it does not have any brushes to wear out and replace.

The proposed work employs two power sources in parallel combination which includes the battery and super capacitor [1]. They are given to the main circuit via a switch and microcontroller decides which power source has to be utilized over a particular interval of time. The stator current is measured and when it goes beyond certain load conditions, super capacitor helps battery by charging it. The fact is that the super capacitor is used to supply the motor during the peak load condition where the battery will not be as efficient as possible. Figure 1 shows the basic block diagram.

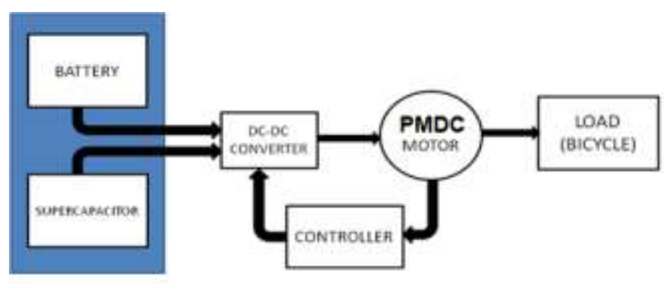

Figure 1:Block diagrarm

(A) Boost Converter or Step-UpConverter

A boost converter is a switch mode DC to DC converter in which the output voltage is greater than the input voltage and the circuit is shown in Fig.2. It is also called as step up converter. The name step up converter comes from the fact that analogous to step up transformer the input voltage is stepped up to a level greater than the input voltage. By law of conservation of energy the input power has to be equal to output power (assuming no losses in the circuit).

Input power (P_{in}) = output power (P_{out})

Since $V_{in} < V_{out}$ in a boost converter, it follows then that the output current is less than the input current. Therefore in a boostconverter;

$$V_{in} < V_{out} \text{ and } I_{in} > I_{out}$$

The equivalent electrical circuit is shown in figure2.

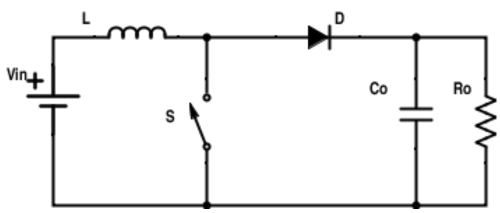

Figure 2: Equivalent Electrical Circuit diagram

The main working principle of boost converter is that the inductor in the input circuit resists sudden variations in input current. When the main switch is turned on, the inductor current rises to the maximum value and energy is stored in the inductor. When the switch is turned off, the polarity of the emf induced in the inductor reverses as it cannot the change the direction of current instantaneously and hence the freewheeling diode is forward biased. As a result, the inductor discharges and the energy stored in it are transferred to the load and the inductor current decays. Therefore, the voltage across the load will be equal to the sum of the supply voltage and voltage across the inductor. Hence, this converter produces an output greater than the input voltage, thus performing boosting action. The large time constant compared to switching period ensures a constant output voltage.

The conversion gain of boost converter is given by

$$\frac{V_0}{V_{in}} = \frac{1}{1-D}$$

Where V_0 is the output voltage, V_{in} is the input voltage and D is the duty ratio of boost converter.

Requirements of the system

The first step in order to project the system is to establish the objectives of the work according to the energy consumption and the performance of the vehicle for individual use. To estimate the power required by this type of vehicles, we have considered that the forces applied to the vehicle are, as represented in figure 1, the following:

$$F_a = M \cdot a \qquad (!)$$

$$F_g = M \cdot g \cdot \sin\theta \qquad (2)$$

$$F_{air} = \cdot 1/2\, \rho \cdot M \cdot C_D \cdot A_f \cdot v(t)^2 \qquad (3)$$

$$F_r = M \cdot g \cdot C_R \cdot \cos\theta \qquad (4)$$

Where: $F_a$is the resulting force; $F_g$is the gravitational force; $F_{air}$is the air friction force; and $F_r$is the wheels friction force; parameter $\rho$is the air density (1.29 kg/m^3); $A_f$is the frontal area of the vehicle; $C_D$is the air friction coefficient (typically 0.9 for a scooter and 0.8 for a bicycle); and $C_R$is the wheels friction coefficient (usually between 0.008 and 0.014).

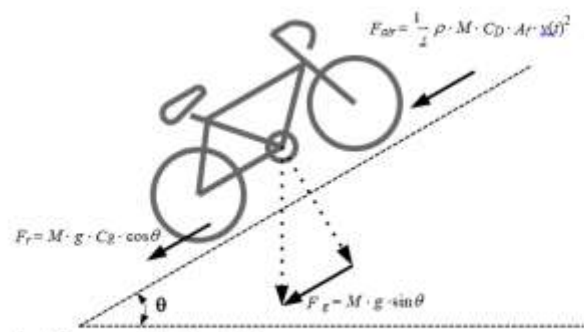

Fig. 1: Forces applied to the vehicle

Considering that the vehicle runs with a speed *v*, the power required by the system is:

$$P_{VE} = P_a + P_g + P_{air} + P_r \Leftrightarrow$$

$$P_{VE} = M \cdot a(t) \cdot v(t) + M \cdot g \cdot v(t) \cdot \sin\theta$$

$$+ \cdot \rho \cdot M \cdot C_D \cdot A_f \cdot v(t)^3 + M \cdot g \cdot C_R \cdot v(t) \cdot \cos\theta 2$$

Assuming that the vehicle speed is equal to the angular speed $\omega$of wheels with radius *R*, torque of the traction system can be estimated as:

$$T_{VE} = T_a + T_g + T_{air} + T_r \Leftrightarrow$$

$$\Leftrightarrow T_{VE} = M \cdot a(t) \cdot R + M \cdot g \cdot R \cdot \sin\theta +$$

$$\frac{1}{2} \cdot \rho \cdot M \cdot C_D \cdot A_f \cdot v(t)^2 \cdot R^3 + M \cdot g \cdot R \cdot C_R \cdot v(t) \cdot \cos\theta$$

The control strategy

The first approach to the problem of energy management is based on the calculation of an average value ofthe current i_{DC}demanded by traction system. The average current should be supplied by the mainpower supply, which can be the set of batteries or a fuel cell [3, 14, 15]. The difference between the instantaneous value of the load current i_a and the average value of i_{DC} will be the current supplied by the supercapacitors, i_{SC}.

When the current i_{SC} is positive and the total voltage of the supercapacitors is higher than the energy availability, the break level V_α, a duty-cycle is applied to the semiconductor S_1 (figure 4) running the DC- DC 1 converter as a boost converter. On other hand, if the supercapacitors does not have energy available, that is, the set of supercacitors is discharged or their voltage is under the break level, converter DC-DC 1 is switched off and the main power supply supplies the traction system. For negative values of i_{SC} and if the supercapacitors do not have the maximum load V_β, converter DC-DC 1 runs as buck converter. When the supercapacitors voltage reaches the value V_β, converter DC-DC 1 remains in its stand-by mode.
Anyway, if a fuel cell is used as the main power supply, condition $i_{DC}<0$ cannot occur. If for instance, $i_{DC}$is negative and the supercapacitors are fully load, to guarantee the protection of the fuel cell, converter DC-DC 2 is switched off, that is, the power supply and load are disconnected. The circuit is shown in figure3.

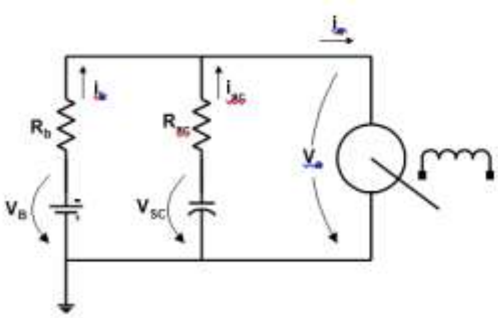

Figure 3: Basic circuit

Motor Controller

Motor controller is the on-board computer that controls all aspects of your e-bike. Its main task is to connect the power, the motor and the sensors, and make sure everything runs smoothly. Inside the controller is a circuit board that manages voltage and amperage input and output, and controls all of the critical functions of your e-bike.

An e-bike controller gets energy from the battery and directs it to the motor according to the user and sensor inputs. It monitors battery voltage, bike speed, motor power, pedaling activity and more.Figure 4 shows the circuit diagram of a controller.

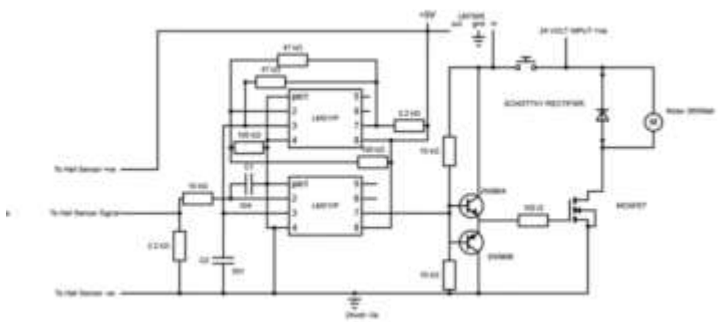

Figure 4: Circuit diagram of a Controller

HARDWAREIMPLEMENTATION

The hardware for the design and implementation of electric bicycle consists of an PWM IC to generate gate pulses to the switch, a converter circuit and a PMDC motor. The gating

circuit includes the optocoupler arrangement. The supply voltage for the opto coupler IC is provided from lead acid battery. The supply voltage is 24 V. The gating circuit is as shown the following:

The converter circuit

The converter circuit consists of power MOSFET, fast recovery diode, output filter capacitor and output load as shown.The input to the converter is given from a series Batteries. The output of the converter is given to the PMDC Motor controller.
The hardware implementation of the proposed work is executed and the output voltage of 36V is obtained. The prototype of the

electric cycle is shown is shown in figure 5.

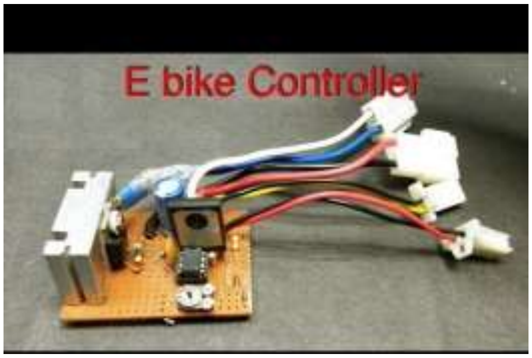

Figure 5: Prototype

Figures 6 and 7 shows the built model.

Figure 6:Overall view of bicycle

Figure 7:Braking Mechanism

CONCLUSION

The proposed work provides a hybrid storage system which increases the run time of bicycle, making the system economic and efficient. Various converter topologies like the interleaved boost converter boost converter, modified boost converter are analyzed and a comparison of these topologies is made by calculating the ripple content of the output voltages.Modified boost converter with its simple circuit, less switching losses, low ripple content is chosen for the hardware implementation. For an input voltage of 36V, the bicycle runs at the speed of 25km/hr. Thus by using this hybrid powered electric bicycle we can have pollution less environment.

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