Minimizing Energy Losses in Hybrid Storage System of the modern E-bikes by using Optimized Adaptive Control

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Abstract

Electric propulsion systems provide cost-effective solutions and are of great interest for companies in order to gain competitive edge in the market. In this respect e-bikes are becoming more and more attractive as they possess the advantage of high energy efficiency compared to other energy forms. This paper proposes a simulation model of an optimal adaptive control strategy for the traction drive in e-bikes. The simulated model will be compared with the experimental setup measurements obtained. Our proposed e-bike uses a hybrid storage system solution. The main idea is to find a good balanced solution between existing Li-Ion Battery and Supercapacitor. We have some samples of Li-Ion Battery proposed by manufacturers and need to choose an optimal value for super capacitor. In this paper we will presents a new numerical simulation method to calculate transient voltage profiles of lithium-ion batteries. In simulation we will use the mathematical equation to describe the functionality of the system. Based on this real equation we can propose and evaluate the real conditions and constrains. We can propose based on functional model of Li-Ion battery and supercapacitor some example for practical setups. This will be beneficial for implementation of BMS (Battery Management System).

The optimal design of the controller is required for the power management in order to reduce the energy losses during acceleration and braking processes. The paper describes the design of the controller used for e-bikes produced "in house" at the "1 Decembrie 1918" University of Alba Iulia. The control unit guarantees a robust operation at different rotor speeds and at different load conditions. The proposed architecture is defined based on the connection between the components that define the energy flow routes and control strategies. In the proposed architecture the electric energy is delivered to the traction drive from a battery via a DC/DC converter.

1. Introduction

Modern e-bikes uses 3-phase BLDC motors. Considering, the phases are shifted 120° from each other, so a convenient method for having a rotating rotor flux in the stator is the six-step commutation scheme, commutating each of the three-phase voltages 60 electrical degrees. At maximum torque and full load, the phase current should have the same waveform as the driving voltage, neglecting the inductive reactance, and the two signals need to be in-phase. In practice the load can vary in a wide range so the evaluation of road and load based on practical measurement will improve the proposed model.

The ability to recover the kinetic energy of the vehicle and store it in the battery pack is an important feature of the electric system of the e-bike. However, finding a technical solution that reduces the energy consumption is required, especially when the e-bike is driven in the

urban traffic areas as the largest part of energy is drawn because the driving cycle involves frequent accelerations and decelerations. In this case, because the power demand varies according to the driving cycle, the traction system is exposed to a variable speed operation. The aim of the control unit is to minimize the power peaks upon applying the torque command. Minimizing the power peaks conducts to an improved performance against “over and under” voltages because the DC link voltage changes upon a sudden load variation. This study investigates how to reduce the current peaks during accelerating and braking operations as well as the behavior of the supercapacitor to reduce the energy loses. The current peaks can be utilized by recharging the supercapacitor until a voltage set point value is reached.
Due to the time-variations of the system parameters, the control unit has to take these variations into consideration. Therefore, an adaptive control method is proposed, in which the values of the controller parameters are modified during the system operation in real time in order to achieve good level of performances. This paper is organized as follows: Section 2 presents the BMS and Energy Power measurement methodology, section 3 presents the characteristics of driving dynamics and validation of energy impacts, section 4 disclose the optimised adaptive control for energy losses, section 5 discloses results and discussions and section 6 presents some conclusions an, future work.

2. BMS and Energy Power measurement methodology

According to the objectives of this work, this section is divided into two parts. Firstly, the methods and materials to perform the “on-road” monitoring of bicycles are explained. The designed methodologies for “on-road” data evaluation of these technologies are presented in the final part.

In order to quantify the real impacts of vehicles under on-road conditions, the Vehicle Specific Power (VSP) methodology is commonly used to perform an energy and environmental characterization of the vehicle monitored (Gonçalves, 2009; Jiménez-Palacios, 1999; Frey, 2007; Zhai et al., 2008). This analysis provides an estimate of the power per mass unit due to a combination of vehicle dynamics (speed, acceleration, rolling and aerodynamic resistance) and road grade as well as to each point of the trip a correspondent specific power is assigned. This methodology allows comparing different technologies under similar power requirements. However, for bicycles and motorbikes only simplified approaches have been performed (Wilson, 2004; Ulrich, 2005).

2.1. On-road monitoring

Two types of bicycles were tested. One was pedal assisted with several levels of electric assistance according with the driver request (EB1) and the other was a bicycle that can be used as power on demand1 or as pedal assist2 or as a mixture of both types (EB2) and as ,reference, a conventional bicycle (CB) will be used for evaluate the difference between the electric bike and conventional one. The monitored vehicles characteristics are presented in Table 1.

Table 1
Bike’s characterization.

Bike	Type	Model	Max power (W)	Battery (kWh)	Type of battery	Mechanical/ electrical gear	Vehicle weight (kg)
EB1	Electric bicycle	Chinese	250	0.36	Lead	6	36
EB2	Electric bicycle	Laboratory UAB	500	0.36	Lithium Ion	6	21
CB	Conventional Bike	Standard equiped				6	12

Two routes in Alba Iulia town were selected in order to cover different types of circuits under urban context, covering a wide range of operating and driving conditions. Six volunteers between 23 and 29 years-old performed the bicycle routes.

Both vehicles were monitored several times on each route, 10 times for each bicycle and the total distance traveled was of 114 km, as presented in Table 2.

Table 2
Characterization of the routes

Route	Type	Distance (km)	Average positive grade (rad)	Average negative slope (rad)
R1	Mixed	2,7	0.037	-0.029
R2	Mixed	4,2	0.020	0.017

Each trip was monitored by data collected in road and sent by GSM to local server.

The GPS allows collecting speed, location and also altitude information via an integrated barometric altimeter, which allows calculating road grade based on distance and altitude, following the same reference procedures studies (Duarte et al., 2014; Graver et al., 2011). The GPS was adequately installed inside the backpack, in order to avoid pressure fluctuations due to the movement which could affect the altitude readings and an external antenna was used to avoid GPS signal losses.

Voltage probes were installed directly in the electric bicycle battery terminals, while current measurements were done on the circuit that connects the battery to the electric motor. Current measurements were calibrated before each measurement, by performing a zero adjustment. The signals provided by the probes were collected by a DAQ board installed also on the backpack. For battery voltage signal a voltage divider circuit was installed before the DAQ board to account for the 0–10 V limit of the acquisition device. Both GPS and battery data were collected in a PC using a program developed in Laboratory to integrate the different communication protocols (serial port and NMEA protocol for GPS and analog data via USB port for the voltage and current collected in the DAQ board) that allows the data synchronization, capturing all the equipment readings in a 1 Hz basis.

According to the rider demands, battery data was used to determine, at each second of the trip, the power provided by the battery to the electric motor and, by integrating this information along the trip the cumulative energy spent on the tour can be obtained.

2.2. Methodology design to estimate specific power

The analysis used in this work is based on Vehicle Specific Power (VSP) to estimate the power demand by vehicles, which combines speed (v), acceleration (a) and road grade (h). This methodology allows comparing different technologies under similar power requirements. It is traditionally used on light-duty vehicles (Jiménez-Palacios, 1999) and its generic definition, which includes the forces applied to a moving body, is presented in Eq. (1). The coefficients of the equation are adjusted according to the typology of vehicle monitored (Wilson, 2004). In this case, the coefficients used were adapted for bicycles and motorcycles based on a literature review (Wilson, 2004; Cossalter, 2006; European Commission, 2006; Lin, 2000; Davis and Danusis, 2008). These coefficients allowed to estimate the Bicycle Specific Power (BSP).

VSP equation for light-duty vehicles: [1]

$$\begin{aligned}
\mathrm{VSP} &= \frac{\mathrm{Power}}{\mathrm{Mass}} = \frac{\frac{d}{dt}(E_{\mathrm{Kinetic}} + E_{\mathrm{Potential}}) + F_{\mathrm{Rolling}} \cdot v + F_{\mathrm{Aerodynamic}} \cdot v}{m} (=) \\
(=) & \frac{\frac{d}{dt}\left(\frac{1}{2} m \cdot (1+\varepsilon_i) \cdot v^2 + m \cdot g \cdot h\right) + C_r \cdot m \cdot g \cdot v + \frac{1}{2}\rho_a \cdot C_d \cdot A \cdot (v + v_w)^2 \cdot v}{m} (=) \\
(=) & v \cdot (a \cdot (1+\varepsilon_i) + g \cdot \mathrm{grade} + g \cdot C_r) + \frac{1}{2}\rho_a \cdot \frac{C_d \cdot A}{m} (\cdot v + v_w)^2 \cdot v
\end{aligned} \quad (1)$$

where $E_{Kinetic}$ is kinetic energy, $E_{Potential}$ is potential energy, $F_{Rolling}$ is rolling resistance force, $F_{Aerodynamic}$ is aerodynamic resistance force, ***v*** is speed, ***m*** is mass (21 or 36 kg for the bicycle and 70 kg for the rider), a is acceleration, ***h*** is the altitude, ***θ*** is road grade, ε_i is the effect of translational mass of power train rotating components (0.01), ρ_a is air density (1.2 kg/m3), υ_w is wind speed, A is frontal area (0.50 m^2 for bicycles), g is the gravitational constant (9.81 m/s^2), C_r is the rolling coefficient (0.008 for bicycles) and C_d is the aerodynamic coefficient (1.2 for bicycles). It is worth noticing that wind speed was not accounted, it's not considered on VSP (Jiménez-Palacios, 1999). Since it is difficult to quantify intensity and direction in a second-by-second basis, even considering an average value of wind speed would not be representative, since it could have positive or negative impacts according with relative direction with the biker. However, it should be noticed that when the on-road monitoring was performed there were no windy days.

Using the respective coefficients, the BSP equation for bicycle in (W/kg) is defined by Eq. (2).

$$\mathrm{BSP} = v \cdot [1.01 \cdot a + 9.81 \cdot \sin(\theta) + 0.078] + 0.0041 \cdot v^3 \quad (2)$$

Fig. 1 presents the cumulative frequency of BSP using more than 10 h of on-road data collected with EB1 and EB2. Around 80% of collected data is between 0.86 W/kg and 2.72 W/kg, which corresponds to around 240W and is coherent with literature review(Mendes, Duarte, Baptista, 2015). The highest BSP value was found in an electric bicycle (7.45 W/kg).,

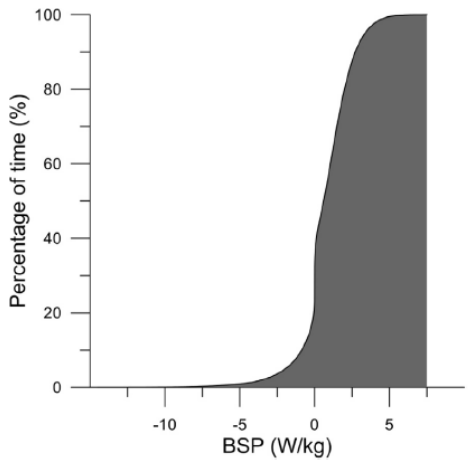

Fig. 1. BSP accumulated frequency for all the monitored data for EB1, EB2.

Unlike vehicles or motorcycles, the maximum power per mass that a human can produce is not explicit, but according with a study performed by Parkin in 2010 in 16 experienced bikers (Parkin and Rotheram, 2010), the speed and acceleration found for different grades is not dependent on age, body mass index, cycling experience, regular use of bicycle and maintenance, amount and shape of baggage. Therefore, the BSP determined from Eq. (2) was assumed to be independent of the biker properties, assuming normal users. The typical power output from bikers can go up to 200W while going uphill (Parkin and Rotheram, 2010), to a maximum of 260W in extreme conditions. According with Wilson (Wilson, 2004), the power output for a regular person is of around 75 W, it can go up to 200–250W for athletic males and athletes under bicycle racing can reach 350–400W consistently, between 20 min to 1 h.

3. Characterization of Driving Dynamics and validation of Energy Impacts

When analyzing the bicycles' data, the percentage of time spent in each BSP mode for the conventional and electric bicycles is presented in Fig. 2. For negative modes, the driving profile is very similar for both bicycles. However, on positive BSP modes, the electric bicycle presents a higher share of time spent in high BSP modes (because of higher power demands). This is a result of the electric assistance, which allows traveling at high speeds on higher slopes and combinations of higher speeds and acceleration. These two BSP profiles allowed creating a change pattern per BSP mode of shifting from CB to EB. Regarding some of the traditional difficulties associated with conventional bicycles, the factor that most influences the speed is the slope of the road, when using conventional bicycles, as it is presented in Fig. 3. In terms of conventional and electric bicycle usage comparison, an overall 16% increase in average speed was verified for the electric bicycle when compared to the conventional bicycle. This increase is mostly visible in positive road grades (37%).

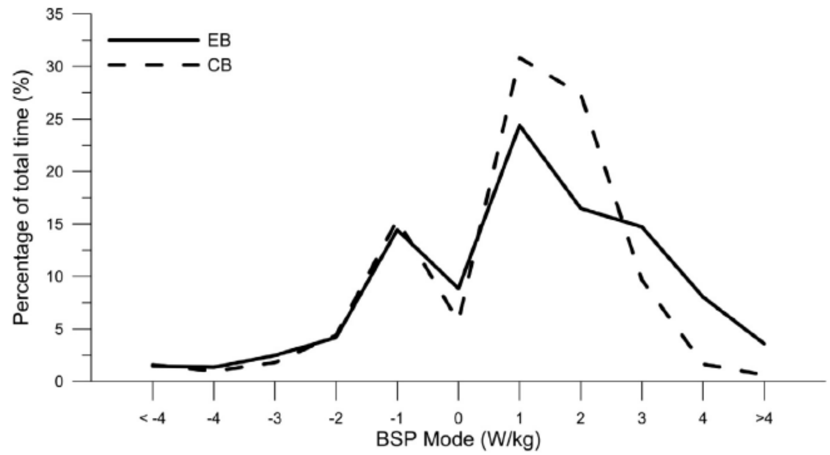

Fig. 2. Time distribution (%) per BSP mode for the two bicycles.

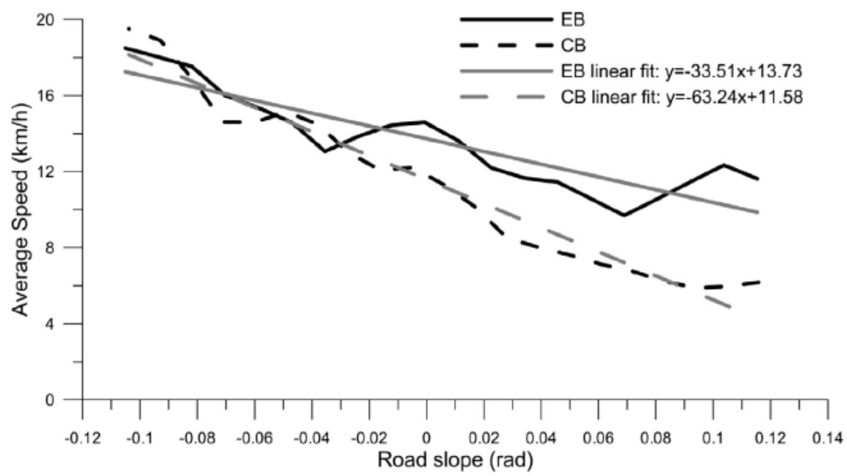

Fig. 3. Speed as a function of road grade.

Fig. 4 presents the average energy consumption rate spent at each BSP mode for the electric bicycles studied, using the 1 Hz data from voltage and current measured at the battery under on-road conditions. It should be noted that the energy characterization provided in Fig.4 reflects the general use of the electric bicycles, regarding electric assistance levels, for the users studied. The differences between users have not been addressed since the objective was to have a generic energy profile and verify the robustness of the methodology regarding the different electric assistance usage patterns.

Unsurprisingly, the energy rate increases with BSP mode, showing the prevalence of electric assistance on these higher modes. The electric bicycles studied did not have regenerative braking, however, on negative modes a small amount of electric consumption is always observed.

In order to validate the modal analysis proposed for bicycles, a comparison between the measured and estimated electricity consumption was performed. Estimates were calculated using Eq. (2), similarly to motorcycles. Table 3 presents the estimated and measured electricity consumption for the two electric bicycles and two routes, performed by 6 bikers, showing that the differences ranged from a minimum of 7.3% to 18.2%. The highest deviations found are a consequence of the different levels of electric assistance used on each route, which can be defined by the rider. On average, the differences found for both bicycles were 1.4% between estimates and measurements, while the absolute deviation was 6.0% and 6.6% for EB1 and EB2, respectively. The results indicate the adequacy and consistency of the BSP approach to quantify the energy use on specific routes.

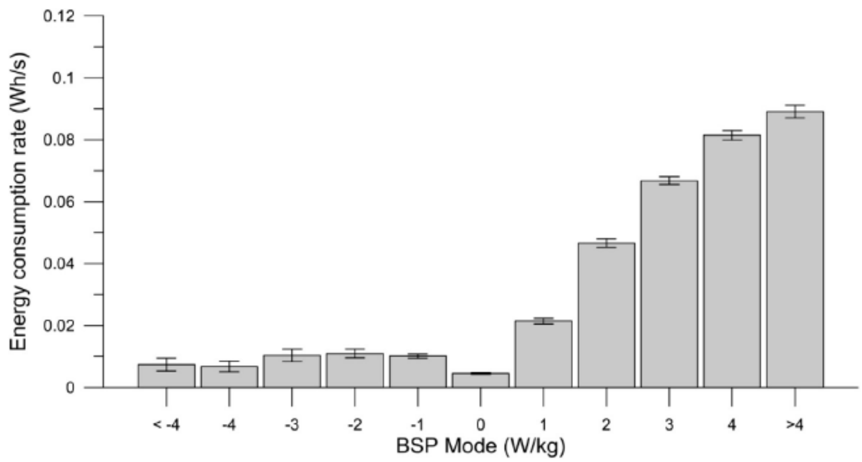

Fig. 4. Electricity consumption rate (Wh/s) for the electric bicycles as a function of BSP.

Table 3
Energy consumption comparison between estimated and real values for EB.

Bicycle	Route	Estimated energy consumption (Wh)	Real energy consumption (Wh)	Difference (%)
EB1	R1	82.9	82.7	0.3
EB1	R1	83.2	70.4	18.2
EB1	R1	87.0	93.9	- 7.3
EB1	R1	77.5	78.1	- 0.8
EB1	R1	75.4	78.1	- 3.5
EB2	R2	132.3	122.4	8.1
EB2	R2	178.3	188.1	- 5.2

Route A connects two major centers in the city, and Route B links two of the major university campus parts, the hostel and the main buildings in Alba Iulia citadel and their characteristics are displayed in Table 4.

The two routes were monitored using two different bicycles, in order to obtain the typical time distribution per BSP mode. Considering that the BSP profiles change according with the technology used, the conventional bicycle BSP time distribution was adapted according to the patterns verified in Figs. 2 and 3. The only constraints used were that each BSP time distribution would have to be equal or higher than 0 and that the sum of all time percentages would have to be 100%. The BSP overall differences are presented in Table 5.

Table 4
Case study route characteristics.

Vehicle	Conventional Bike (CB)	
Route	A	B

Trip time (s)	810	1012
Distance (km)	2.7	4.2
Average positive slope (rad)	0.039	0.010
Average negative slope (rad)	- 0.025	- 0.009
Average speed (km/h)	12	15
Maximum speed (km/h)	32	28

Using the estimated BSP time distribution for the electric technologies, based on conventional ones, a comparison of the impacts of using the electric bicycle in the two routes was performed and is presented in Table 5.

When analyzing the bicycles results, trip time would be reduced by 10% for both routes and the electricity consumption impacts would be reduced by -11%. This would represent electric autonomies of 22 times for Route A and 16 times for Route B.

Table 5
Case study results for using an electric technology.

Vehicle	EB	
Route	A	B
Trip time (s)	751	892
Distance (km)	2.7	4,2
Estimated average speed (km/h)	13	17
Battery capacity (kWh)	0.36	0.36
Electricity consumption (Wh)*	21.12	36.69
Autonomy (km) 30 37	59	66
Autonomy (number of trips)	22	16

The on-road monitoring of electric and conventional bicycles allowed the development of methodologies for analysis of trip dynamics and energy consumption. The Bicycle Specific Power (BSP) were adapted from the Vehicle Specific Power methodology, which allows comparing different propulsion technologies under similar power conditions and is used in numerical tools to provide estimates of vehicle/fleet consumption in specific routes. BSP was defined with 11 modes with a step of 1W/kg, in order to group points with similar specific power, assuring that all modes have at least 1% of the total time and to avoid that specific power time distribution was dominated by a limited number of modes.

Using on-road measurements of speed, acceleration, road grade and electricity consumption measured in the batteries, it was possible to build maps of driving time distribution and energy use according with the specific power for bicycles. These results indicate that electric technologies allow reaching higher power requirement conditions, and quantify higher electricity consumption with increasing power requirements.

Furthermore, regarding electric bicycles, the average deviation between measurements and estimates using modal analysis is 1.41% ± 8.91% and the absolute deviation is 6.20% ± 6.08%. These results indicate that the selected coefficients and the modal analysis development is able to represent typical vehicle characteristics (such as rolling resistance, aerodynamic, etc.) as well as the typical operation of the bicycles.

4 . Optimized Adaptive Control Strategy

This section presents the multi-sources energy models and rule based feedback control algorithm of an energy management system (EMS) for electric bike (EB). The multiple sources of energy, such as a main battery (e.g. Li-Ion, Lead) and super-capacitor (SC), EMS and power controller, DC machine and vehicle dynamics are designed and modeled using MATLAB/SIMULINK. The developed control strategies continuously support the EMS of the multiple sources of energy for prototyping a new electric bike under normal and heavy power load conditions. The performance of the proposed system is analyzed and compared with the data collected and estimated methodology test drive cycle in terms of vehicle speed and load power. This section demonstrates that the proposed control algorithm provides an efficient and feasible EMS for EB.

In order to meet the consumer's requirement such as power, longer travel distance and reliability, EMS and available stored energy need to be design. The battery is used as the primary source of energy, while the SC is used as the auxiliary energy source, and also like extended energy source for a high demand load. In addition of multi-sources, the battery can be charged at home and in the charging point by harvesting solar energy. Thus, the control strategy in the EMS plays an important role: it either enhances the storage capacity or changes the energy sources, as required. The sources of energy models used in the EB system: a shown in Fig..5. Detail energy model are explained as follows.

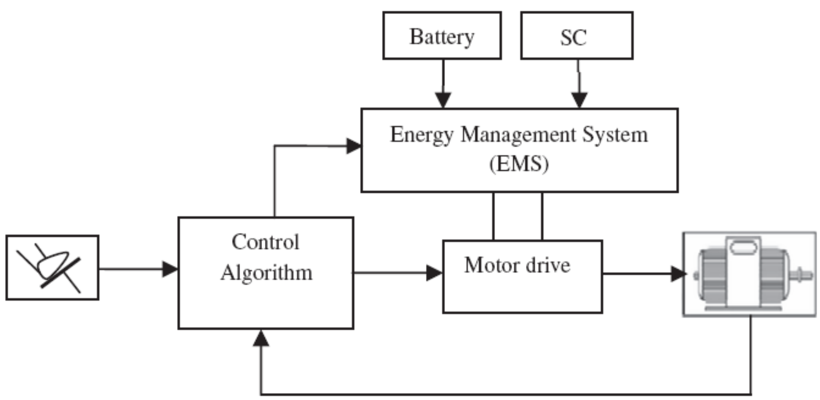

Fig. 5 . Multiple power sources in a closed loop motor drive system

4. 1. Battery model

A lead-acid battery model is used for electric bike. Dimension of the battery is set to have 36 V supply voltage and 10 Ah storage capacities that can support 360 Wh for a maximum charge. That mean the vehicle could travel around 50 km for a single charge. The equivalent circuit of the battery model proposed by MATLAB/SIMULINK can be expressed as in [MathWorks, SimPowerSystems. MATLAB 2008.] as follows.

$$V_{batt} = V_0 - K\frac{Q}{Q - it} + Ae^{(-B \cdot it)} \tag{3}$$

where V_{batt} is constant load voltage and V_0 is no load voltage, K is the polarized voltage constant, Q is the battery capacity, A is the exponential voltage and -B is the exponential capacity of the battery. The load current i and time t is parameterized, respectively.

The Eq. (3) can be related to battery state of charge (SOC) which is presented in [5,22,23] as follows.

$$V_{batt} = V_0 - \frac{K}{\mathrm{SOC}} + Ae^{BQ(\mathrm{SOC}-1)} \tag{4}$$

where SOC is measured as battery state of charge per unit value. The energy discharge from battery can be calculated from SOC as follows.

$$E = V_0 Q(1-\mathrm{SOC}) - KQ\left(1+\frac{1}{\mathrm{SOC}}\right) + AQ(1-\mathrm{SOC})e^{BQ(\mathrm{SOC}-1)} \tag{5}$$

The battery is discharge until the SOC is at 30% and then SC will be switch on. The SOC level should be high enough since the startup for SC may take from seconds to several minutes. When the SC is in full operation, battery supply is cut off. Battery will be only in action when SC has problem during transient energy demand and response.

4. 2. Supercapacitor model

The SC energy storage system is designed to aid the battery when there is high demand for power in the vehicle. The modeling of SC is related to the basic discharging circuit of the capacitor voltage in terms of the resistor and capacitor, RC circuit. The effective discharging voltage depends on the initial voltage of the capacitor and the RC time constant, which is described by [Uzunoglu M, Alam MS, 2007.] as follows:

$$V_{SC}(t) = V_i e^{\left(-\frac{t}{RC}\right)} \tag{6}$$

where V_{SC} is SC voltage and V_i is initial voltage The amount of energy delivered by the SC is directly proportional to the capacitance and voltage changes throughout discharge defined in [Hannan MA 2005] as follows:

$$E = \frac{1}{2}C(V_i^2 - V_f^2) \tag{7}$$

where V_f is final voltage and C is capacitor value

A number of SCs are arranged in series and parallel to provide a certain amount of energy during acceleration and peak load demand.

The total resistance R_{total} and capacitance C_{total} of the SC module is calculated in [Hannan MA, Ghani ZA, Mohamed A 2010 and Sharma P, Bhatti TS, 2010] as follows:

$$R_{total} = n_s \frac{ESR}{n_p} \qquad (8)$$

$$C_{total} = n_p \frac{C}{n_s} \qquad (9)$$

where n_s is number of capacitors in series, n_p number of capacitors in parallel and ESR is equivalent series resistance. By the Eqs. (7)–(9), the SC module dimension is designed to having 14 V and 20 F. The total energy at the half-voltage is about 1200 Ws (J). It is enough to support if battery losing power in time.

4.3. Energy management system (EMS)

The EMS controls all of the energy sources that have different tasks in delivering power to the load. The battery is the main energy source of the vehicle. Once the start button is triggered, processors determine the battery capacity and the pedal acceleration.

Then, the EMS determines which energy sources should be activated. The SC is the secondary energy source, starts supplying energy to the load and recharges the battery when the battery capacity is below 30%. If the battery reaches 80% of its capacity, the SC supply is cut off. The SC supports energy sources when the battery take a longer time to support high power demands. After the EMS has been triggered, it recharges and waits for the next request.

The control strategies of the EMS are depending on rule based feedback the control parameters. The feedback control parameters such as the acceleration pedal (PO), battery SOC (BC) and electric bike speed (PD) are used to control activation of multi sources of battery and SC, respectively. All the control switches follow the rules that have been described in control algorithm.

A control algorithm is designed to fulfill the condition based on the situation and to maximize energy conservation. The operational control strategies are based on the seven operation states. The main task of the system is to maintain the power source to drive the BLDC motor. The controller determines three basic operational input conditions: pedal offset (PO) and power duration load (PD) are determined by measuring motor speed over a long period of time, and battery capacity (BC). Based on the source conditions, the seven operational states are as follows:

State 1: (Input: Safety Button): Off operation/safety features.
State 2: (Input: BC + /PD + /PO): Battery is fully used to drive the motor if there is no high power demand. Part of the energy is conserved;
State 3: (Input: /BC + /PD + /PO): SC takes over to drive the vehicle and charge the battery until it turns to state 2.
State 4: (Input: BC + PD + /PO): The consequence of a high power demand forces the system to activate the SC as the auxiliary energy source.
State 5: (Input: BC + /PD + PO): In this situation, the battery-powered vehicle accelerates with the support of the SC. The vehicle then turns to state 2 after all energy in the SC is used.
State 6: (Input: /BC + /PD + PO): The battery is critical. The SCpowered vehicle accelerates with additional energy from the SC. After the SC tank is empty, the system changes to state 2.
State 7: (Input: BC + PD + PO): As the vehicle moves into high speed and requires acceleration, the system is forced to activate all of its energy sources.

4.4. Power control System

Before link to multi-switches, all energy sources are connected to the DC converter to raise the source voltage to rated voltage for BLDC machine. Then they are linked to the multi-switches which contain a power control switch that allow current flow when it is activated. Switch activation depends on the input from pedal acceleration (Po), battery SOC (Bc) and high power demand load (Pd).

The detailed system that controls the switches and the current for the vehicle power load is shown in Fig. 6. The outputs current i.e., supply current is the combination of currents from the battery and the SC sources. The current controlled source includes a PI controller that determines the reference current from the measuring actual speed and the reference speed of the vehicle [Uzunoglu M, Alam 2007].

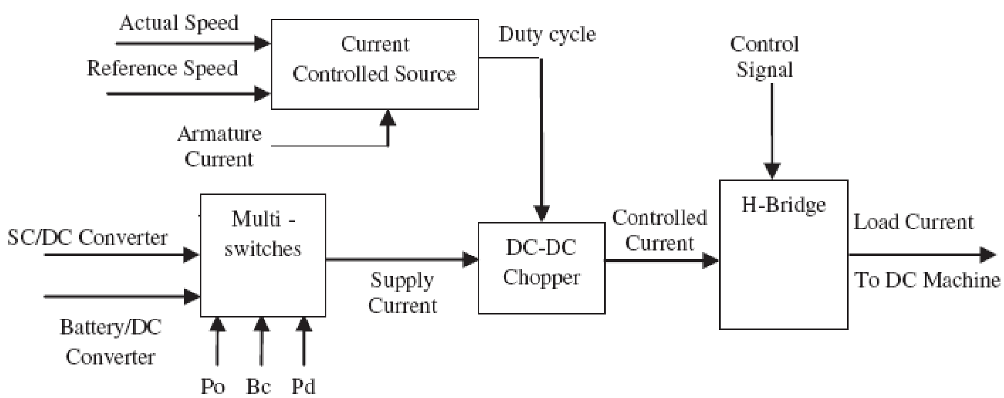

Fig. 6 . Power control system for the electric bike.

Matlab / Simulink model for electric bike

The vehicle system simulation model is shown in Fig. 7. The model consists of feedback and control system, multi-sources, EMS and power control, BLDC machine and vehicle load. The feedback and control system block detect feedback measurement such as pedal acceleration, battery SOC and vehicle speed and then convert into digital signal to EMS block.

The EMS block will make decision from the input data based on control algorithm to set the sources and control the current supply to BLDC machine according to the reference speed .

In the BLDC machine block consist of DC motor rated 36 V, 500W. In order to have better efficiency of BLDC, a higher rated voltage is recommended. All parameter of the forces exerted to the vehicle are in the vehicle load block. Then the actual speed is compared to the reference speed of a CB.

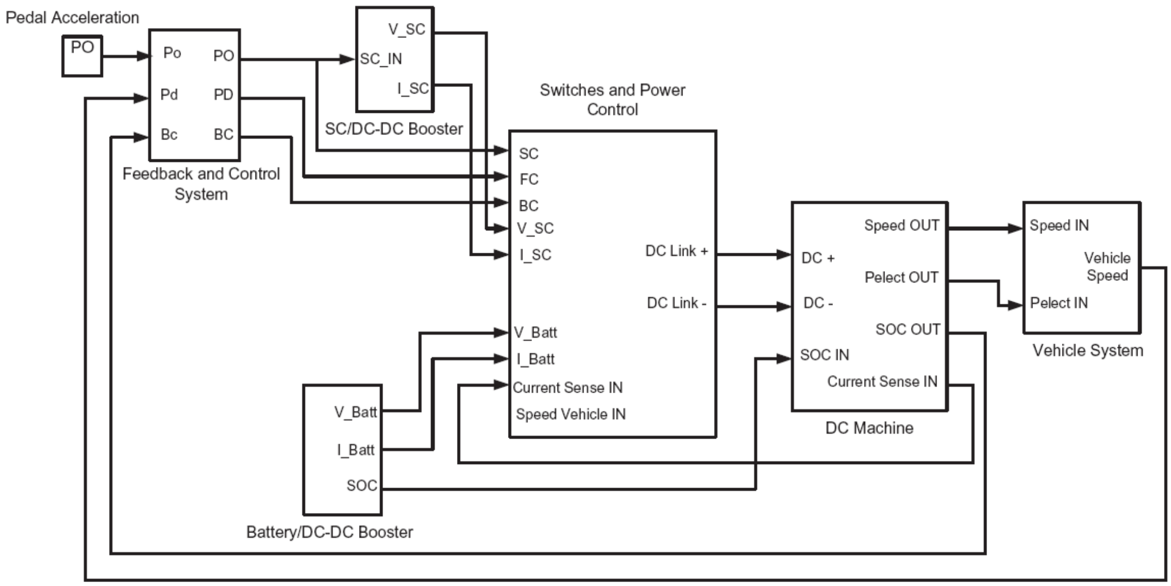

Fig. 7 . Electric bike model in MATLAB/SIMULINK.

5. Results and discussions

The performance evaluations for the EMS of the Electric Bike Model, are investigated in terms of vehicle speed, power load and multiple source loading conditions. The developed system is compared with that of the CB drive cycle to validate the proposed model.. It is observed that the results of the motor speed and the test drive cycle are closely matched together except during the step-down of the vehicle.

Because the deceleration speed of the motor is controlled by the PI regulator, a dampening response is clearly observed in practice. It is also seen that several seconds are needed to regulate the motor speed to reach a constant speed. When it reaches a constant speed, over-braking and acceleration occur before the system can settle at a constant speed. For the next deceleration test until the vehicle stops, the dampening response rises again, and several seconds are needed to regulate the vehicle's speed until it stops. By applying the control algorithm, the vehicle system drives in state 2. The vehicle system is designed so that the battery-powered system has the ability to support the vehicle as it travels short distances. Because the test drive cycle is a short-distance test, the vehicle system has no trouble following the test cycle. In this test, the problem is during deceleration, when the PI regulator must be more efficient to create a precise duty cycle to control the vehicle's speed during braking.

In this vehicle system, battery has two task such as providing electrical energy and used as energy storage. Battery is constantly burdened by the activity of charge and discharged through plug-in or solar harvesting. However, these activities make the vehicle more economical. Though the battery life-span is shortened easily, however, Li-ion or NiMH battery can be replaced due to its better life cycle and less weight.

The battery energy storage is a key factor for the future electric vehicle. Thus, the high energy storage, less expensive, longer life cycle and less charge time of the battery is to be required capable.

At this moment, energy density and high demand power is aided by SC.
Both EB demonstrate the need to achieve an optimal balance between energy storage and generator sizes. This impacts both the fuel economy and overall vehicle costs.
The EB is significantly cheaper than all alternatives; however this needs to be weighed against more frequent charging of the system. Nevertheless, a pack size between 10 and 20 Ah is favorable to achieve most daily drives.

6. Conclusions

Regarding the future possibilities of using electric bicycles in urban sharing systems with the testing of representative routes, the application of the designed methodologies was performed in order to understand the real impacts of using these technologies for an application in Alba Iulia town. In this sense, two routes in the city center were monitored using the conventional technologies. Conventional technologies were chosen as a basis for this case study, since they are very common and consequently more available to perform a consistent analysis of the routes that could pave the way for using the methodology developed within this work and to assess the impacts of changing to electric technologies. Combining the hybrid storage system and load based on the real measurement of the road parameters will improve the accuracy of the proposed practical model for e-bikes that will be use in Alba Iulia town.

The designed methodologies were applied to two specific routes in the city of Alba Iulia. The results indicate a decrease in trip time (-10%) for EB compared to CB For the bicycles, an additional energy use is accounted in EB due to the battery electricity consumption.

The concept presented in this work for on-road monitoring of bicycles and motorcycles allowed the development of the BSP methodologies in order to chose the strategies for Charging and recovery the energy on road. These methodologies are innovative since, based on an easily collected driving cycle (speed, acceleration and grade variables), the evaluation of the impacts of alternative technologies can be easily performed. This can be regarded as an added value, for instance, when examining mode share potential for conventional methodologies for an analysis of specific routes, using conventional technologies and estimating the impacts of electric solutions, including travel time, energy consumption and electric autonomy.

References:

Magno Mendes, Gonçalo Duarte, Patricia Baptista, Introducing specific power to bicycles and motorcycles:Application to electric mobility, Transportation Research Part C 51 (2015) 120–135

Baptista, P., 2013. On-road monitoring of electric bicycles and its use in bike-sharing systems. In: Silva, C. (Ed.), Grid Electrified Vehicles: Performance,
Design and Environmental Impacts. Nova Science Publishers Inc.

Baptista, P., Silva, C., Farias, T., Heywood, J., 2012. Energy and environmental impacts of alternative pathways for the Portuguese road transportation sector.
J. Energy Policy 51, 802–815.

Bishop, J., Doucette, R., Robinson, D., Mills, B., McCulloch, M., 2011. Investigating the technical, economic and environmental performance of electric
vehicles in the real-world: a case study using electric scooters. J. Power Sources 196, 10094–10104.

Cherry, C., Cervero, R., 2007. Use characteristics and mode choice behavior of electric bike users in China. Transp. Policy 14, 247–257.

Khayyam H, Abawajy J, Javadi B, Goscinski A, Stojcevski A, Bab-Hadiashar A.
Intelligent battery energy management and control for vehicle-to-grid via cloud computing network. Appl Energy 2013;111:971–81.

Capasso C, Veneri O. Experimental analysis on the performance of lithium based batteries for road full electric and hybrid vehicles. Appl Energy 2014;136:921–30.
Scrosati B, Garche J. Lithium batteries: status, prospects and future. J Power Sources 2010;195:2419–30.

Veneri O, Migliardini F, Capasso C, Corbo P. Experimental performance assessment of Pb, Li[NiCoMn]O2 and LiFePO4 batteries for road vehicles. In:International symposium on power electronics, electrical drives, automation and motion, Sorrento, Italy; 2012. Print ISBN: 978-1-4673-1299-8.

Waag W, Käbitz S, Sauer DU. Experimental investigation of the lithium-ion battery impedance characteristic at various conditions and aging states and its influence on the application. Appl Energy 2013;102:885–97.

Uzunoglu M, Alam MS. Dynamic modeling, design and simulation of a PEM fuel cell/ultra-capacitor hybrid system for vehicular applications. Energy Convers Manage 2007;48(5):1544–53.

Hannan MA, Mohamed A. PSCAD/EMTDC simulation of unified series-shunt compensator for power quality Improvement. IEEE Trans Power Delivery 2005;20(2):1650–6.

Hannan MA, Ghani ZA, Mohamed A. An enhanced inverter controller for PV applications using dSPACE platform. Int J Photoenergy 2010;2011:10.

Sharma P, Bhatti TS. A review on electrochemical double-layer capacitors. Energy Convers Manage 2010;51(12):2901–12.