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An Investigation of Increasing the Performance of Electric Rickshaw - Pedicab Batteries

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Abstract— *As electric cars are environmentally friendly, their use will reduce air pollution. Electric pedicabs, which are designed to solve the transportation problems of people from electric vehicles designed for different purposes, are widely used in many cities, especially since they are a very effective means of transportation in the city. However, serious research is needed on increasing the performance of the electric rickshaws, especially their batteries. The most important factor that determines the vehicle's range is the capacity of the vehicle's battery. In this study, it has been shown that it is possible to use battery for longer periods with some important changes by conducting a research on pedicab batteries.*

Keywords—electric pedicab; batteries technology; Li-Ion batteries;

1. INTRODUCTION

An electric pedicab or rickshaw actually has a traditional bicycle case, pedals, cranks, chain and free wheel assembly. Thanks to the electric drive, man can change or reinforce the muscle strength. It adds an electric motor, gear reducer, battery and power control to the bike. Pedicab, a different type of electric vehicle, is capable of carrying three people except the driver. On the other hand, the city is also a clean transport vehicle with no carbon dioxide emissions. This type of transport habit is also an environmentally friendly and spacious alternative to the congestion of crowded transportation vehicles, especially in very crowded city centers. This work is about the battery, which is as important as the motor and power transmission system for the efficient use of three-wheel electric bicycles called pedicab. An electric assist requires the addition of an electric motor to a modified rickshaw frame, as well as energy storage in rechargeable batteries. While a working electric assist could be extremely beneficial to drivers, there are a number of constraints which limit design and feasibility. In addition, ability to do local manufacture and repair is an important consideration when beginning to outsource parts like batteries and motor systems. While electric assist systems have been developed, there are many questions and tests that need to be done in order to determine if this solution is a feasible one for drivers at the pedicab. Bicycle rickshaws are a widely used method of transportation throughout India. The basic rickshaw is a three-wheeled tricycle design, pedaled by a human driver in the front, and with a bench seat in the rear for passengers or for conveying goods and luggage (Fig. 1.). As with a taxi, passengers pay the rickshaw driver a fee to transport them from one place to another [1].

Fig. 1. *Traditional pedicabs.*

2. ELECTRICAL SYSTEM OF PEDICABS

The electric system of the assist is relatively simple, consisting of batteries, motor, motor controller, and a wattmeter and power analyser for taking power measurements [2]. The operating principle of the electric Pedicab vehicle is briefly explained in Figure 2. The most important parts of the electric system of an electric pedicab are; It can be defined as motor, motor drive, battery, communication cables and gearbox.

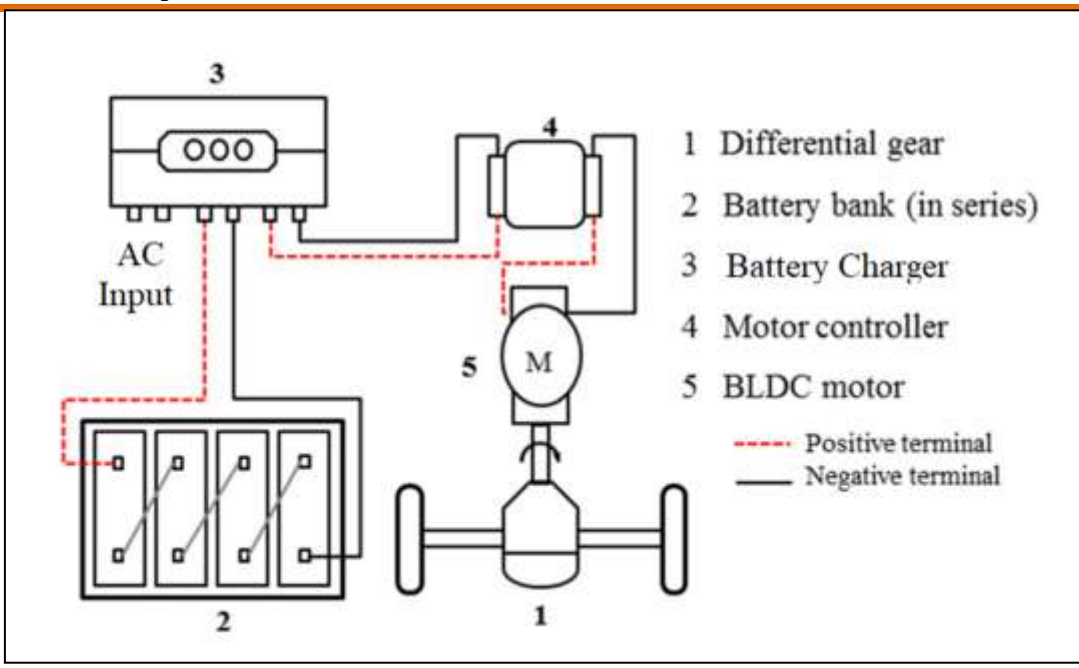

Fig. 2. *Electrical setup of the electric pedicabs[2].*

3. Battery

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3.1 Battery Technologies Used in Electric Vehicles

Define There are various battery technologies in the market with different rated voltage and energy density. Battery technologies and features that are commonly used in electric vehicles and are under investigation are given in Table 1[3].

Lithium Ion Polymer (LiPo) Batteries

They have almost the same characteristics as lithium ion batteries. The only difference between them is the use of polymer material as an electrolyte in lithium ion polymer batteries. The electrical conductivity of the polymer electrolyte material is higher than that of other organic liquid electrolytes. In addition, the use of this material allows the lithium polymer batteries to be produced more easily, faster and in different ways.

Lithium Iron Phosphate (LiFePO4) Batteries

The positive electrode material is lithium based batteries with lithium iron phosphate. It has advantages such as high energy density, high conversion rate and more reliable use. However, the performance is lower compared to lithium ion batteries.

Lithium Sulfide (Li-S) Batteries

Lithium-based battery groups as the cathode material is the use of sulfur batteries. High energy density, high charging efficiency, low cell voltage and average cycle life are batteries.

Table 1: Battery technologies used in classic electric vehicles

Battery Types	*Voltage (V)*	*Energy Density (Wh/kg)*	*Memory Effect*	*Operating Temp.(°C)*	*Cycle Life*
Li-air	2.9	1300-2000	No	-10, +70	100
Li-S	2.5	350-650	No	-60, +60	300

Battery Types	*Voltage (V)*	*Energy Density (Wh/kg)*	*Memory Effect*	*Operating Temp.(°C)*	*Cycle Life*
Zn-air	1.65	460	No	-10, +55	200
$LiFePO_4$	3.2	120	No	-45, +70	>2000
LiPo	2.7	130-225	No	-20, +60	>1200
Li-ion	***3.6***	***118-250***	**No**	***-20, +60***	***2000***
Zebra	2.6	90-120	No	+245, +350	>1200
NiMH	1.2	70-95	No	+245, +350	1200
NiCd	1.2	50-80	Yes	-20, +50	2000
Pb-acid	2	35	No	-15, +50	1000

Lead-Acid (Pb-Acid) Batteries

Lead-acid batteries are an old and common technology used in many applications. Lead-acid batteries contain lead in the negatively charged electrode, lead-dioxide (PbO2) in the positively charged electrode and sulfuric acid (H2SO4) materials in electrolyte. This battery technology has important advantages such as high discharge current, low self discharge, no memory effect and low cost. However, these batteries have low nominal voltage and energy density. In addition, battery life is reduced when not in use.

Nickel Cadmium (NiCd) Batteries

Nickel cadmium batteries are safe and inexpensive technology. In the case of nickel cadmium batteries, the negatively charged electrode uses cadmium / cadmium hydroxide (Cd / Cd (OH) 2), the positively charged electrode uses nickel hydroxide / nickel oxyhydroxide (Ni (OH) 2 / NiOOH) and potassium hydroxide (KOH) as electrolyte. These high discharge current batteries have a higher energy density than lead-acid batteries. However, this battery technology has significant drawbacks. These are poor charge / discharge efficiency, high self discharge and memory efficiency.

Nickel Metal Hydrate (NiMH) Batteries

Nickel metal hydrate battery technology has been developed as an alternative to the disadvantages of nickel cadmium batteries. Cadmium electrode was used instead of metal hydrate. Nickel metal hydrate batteries have a higher energy density while the nominal voltage values are equal. However, nickel metal hydrate batteries have a higher rate of self-discharge compared to nickel cadmium batteries and lower reliability in case of overcharging.

Li-ion Batteries

Lithium metal oxides are used as a positive electrode in lithium ion batteries with the advantage of low toxicity, high capacity and cheapness compared to other materials. Commonly used oxides: Lithium cobalt oxide - LiCoO2, Lithium nickel oxide - LiNiO2, Lithium manganese oxide - LiMn2O2. Lithium-ion battery technology has different properties than nickel-based battery technologies. It has higher rated voltage and higher energy density than nickel based battery groups.

3.2 Battery Modeling Methods

The performance and life of a battery depend on the safe working area. This field of work improves the performance of the batteries by preventing the dangers that may occur in the cases of overcharging and discharging. It is the unit's battery management system that enables the batteries to operate in this safe area in terms of safety and performance. Battery status estimations that have an important place in the battery management system directly from the battery. It can not be measured. Therefore, an accurate battery model is required with measurable values. There are different techniques related to battery modeling methods in literature. These methods include experimental, statistical, electrochemical and electrical circuit models.

Experimental circuit models

In the experimental circuit model, the physical model of the system is created with the help of physical equations and the parameter values in the model are determined by experimental results. It is a simple method to apply and quick results can be obtained. However, the accuracy of the results is not a very preferred method because it is low.

Statistical Circuit Models

In the statistical circuit model, parameter values in the system model are obtained by creating meaningful structures from the obtained data samples. As in the experimental circuit model is a simple and fast method to apply. However, accuracy performance is not preferred because it is not sufficient.

Electrochemical Circuit Models

Electrochemical circuit models are based on the processes of chemical structure of the battery. In this way, the battery contains a direct relationship between the battery status, such as the charge status and temperature. However, this structure contains complex processes. Therefore, it is difficult to implement and is not preferred.

Electrical Circuit Models

In electrical circuit model, system model is formed by equivalent circuits. The battery model created with equivalent circuits enables mathematical operations to increase the accuracy of the battery model. There are different equivalent circuit models used in the literature. These can be given as Rint model, RC model, PNGV model and Thevenin model. Rint model equivalent circuit Figure 3., the equivalent circuit of the RC model is shown in Figure 4., the equivalent circuit of the PNGV model is given in Figure 5.

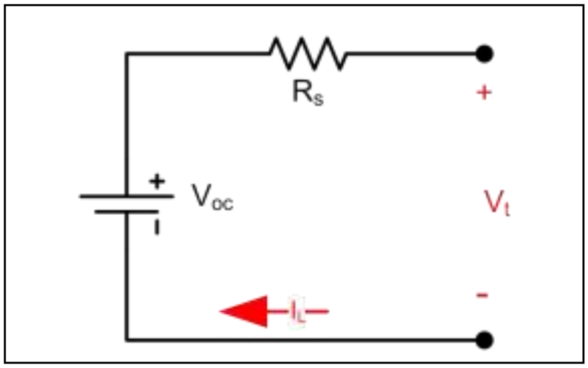

Fig. 3. *Rint equivalent circuit model.*

Here, R_s; series resistance, V_{OC}; open circuit voltage, Vt; terminal voltage and I_L load current. The mathematical equation of the Rint model over the equivalent circuit is obtained as follows.

$$V_t = V_{OC} - R_s I_L \quad (1)$$

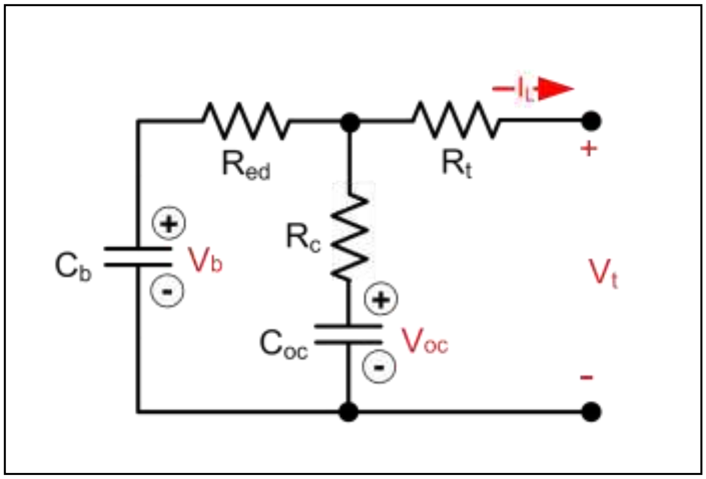

Fig. 4. *PNGV equivalent circuit model.*

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The abbreviations here are R_{ed}; edge resistance, R_C; capacitor resistance, R_t; Terminal resistance, C_b; the stack capacitor, C_{oc}; small capacity surface capacitor, V_b and V_{oc}; respectively; C_b and C_{oc}; the voltages, I_L; load current and V_t; terminal voltage. The mathematical equation of the RC model over the equivalent circuit is obtained as follows.

$$\begin{bmatrix} U_b \\ U_{oc} \end{bmatrix} = \begin{bmatrix} -1/C_b(R_{ed}+R_c) & 1/C_b(R_{ed}+R_{oc}) \\ 1/C_{oc}(R_{ed}+R_c) & 1/C_{oc}(R_{ed}+R_{oc}) \end{bmatrix} \begin{bmatrix} U_b \\ U_{oc} \end{bmatrix} + \begin{bmatrix} -R_c/C_b(R_{ed}+R_c) \\ R_{ed}/C_{oc}(R_{ed}+R_c) \end{bmatrix} I_L \quad (2)$$

$$U_t = [R_c(R_{ed}+R_c) \quad R_{ed}(R_{ed}+R_c)] + \begin{bmatrix} V_b \\ V_{oc} \end{bmatrix} + \left[-R_t - \frac{R_{ed}R_c}{(R_{ed}+R_c)}\right] I_L \quad (3)$$

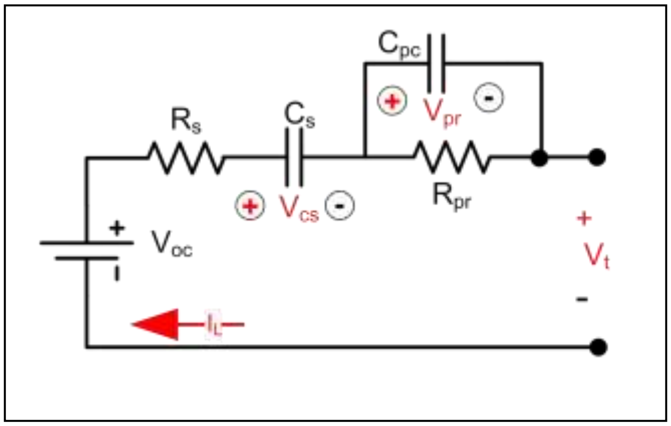

Fig. 5. *PNGV equivalent circuit model.*

The abbreviations in the circuit are R_s; series resistor, C_s; series capacitor R_{pr}; polarization resistance, C_{pc}; polarization capacitor, I_L; load current, V_{OC}; open circuit voltage and V_t; terminal voltage. The mathematical equation of the PNGV model over the equivalent circuit is obtained as follows.

$$U_d = \frac{I_L}{C_s} \quad (4)$$

$$V_{pr} = -\frac{V_{pr}}{\mathrm{R}_{pr}C_{pc}} + \frac{I_L}{C_{pc}} \quad (5)$$

$$V_t = V_{oc} - V_{cs} - V_{pr} - I_L R_s \quad (6)$$

Thevenin equivalent circuit model in the electrical circuit model can be modeled at different degrees. Thevenin equivalent circuits of different degrees are given in Figure 6.

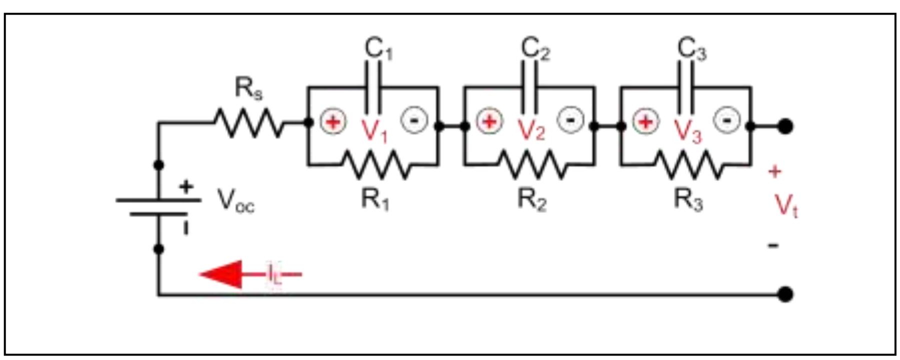

Fig. 6. *Rint equivalent circuit model.*

Here is V_{OC}; open circuit voltage, R_s; series resistance, R_1, R_2, and R_3; block resistance parameters, C_1, C_2,and C_3; block capacitor parameters and V_t; terminal voltage. Equations of first order Thevenin equivalent circuit are as follows,

$$V_t = V_{oc} - V_1 - I_L R_s \qquad (7)$$

$$C_1 \frac{dV_1}{dt} = -\frac{U_1}{R_1} + I_L \qquad (8)$$

Equations of the second order Thevenin equivalent circuit are as follows,

$$V_t = V_{oc} - V_1 - V_2 - I_L R_s \qquad (9)$$

$$C_1 \frac{dV_1}{dt} = -\frac{U_1}{R_1} + I_L \qquad (10)$$

$$C_2 \frac{dV_2}{dt} = -\frac{U_2}{R_2} + I_L \qquad (11)$$

Equations of the second order Thevenin equivalent circuit are as follows,

$$V_t = V_{oc} - V_1 - V_2 - V_3 - I_L R_s \qquad (12)$$

$$C_1 \frac{dV_1}{dt} = -\frac{U_1}{R_1} + I_L \qquad (13)$$

$$C_2 \frac{dV_2}{dt} = -\frac{U_2}{R_2} + I_L \qquad (14)$$

$$C_3 \frac{dV_3}{dt} = -\frac{U_3}{R_3} + I_L \qquad (15)$$

The battery charge rate is calculated by the amper-hour counting method as follows.

$$S_0 C_t = S_0 C_0 - \frac{1}{C_b} \int_0^t \eta \, I_{Lt} dt \qquad (16)$$

Here, S_0C_t; available battery occupancy rate, S_0C_0; starting battery occupancy rate, C_b; the maximum available capacity, η; coulomb efficiency and I_{Lt}; load current. S_0C_0, which is the initial battery charge ratio, is usually obtained experimentally with open circuit voltage method and kalman based filters. The maximum available capacity value C_b can be obtained from laboratory measurements or from battery manufacturers. The coulomb efficiency η is expressed as follows.

$$\eta = \frac{\int_0^{t_d} I_d dt}{\int_0^{t_c} I_c dt} \qquad (17)$$

Here is I_d; discharge current, I_c; charging current, t_d; Discharge time and t_c; charging time.

4. MATLAB / SIMULINK MODEL OF LITHIUM ION BATTERY

Many methods of modeling lithium ion battery are used. In this study, the 2nd degree Thevenin equivalent circuit (Fig. 7.) is preferred among the electrical circuit models which have high model accuracy and not easy operation.

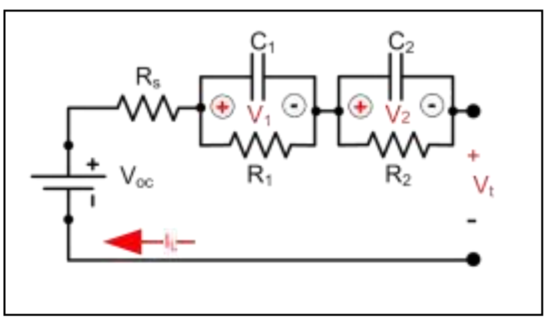

Fig. 7. *Secondary 2nd degree Thevenin equivalent circuit model.*

The parameters used for the Li-Ion battery are given in Figure 8. The circuit model in which the whole system is connected to a 10 ohm load is given in Figure 9. The results of the SOC-time (s), Load Voltage-time (s) and Load Current-time (s) graphs are given in Figure 10. Accordingly, a decrease from 3.2V to 2.7V is seen in 20 seconds.

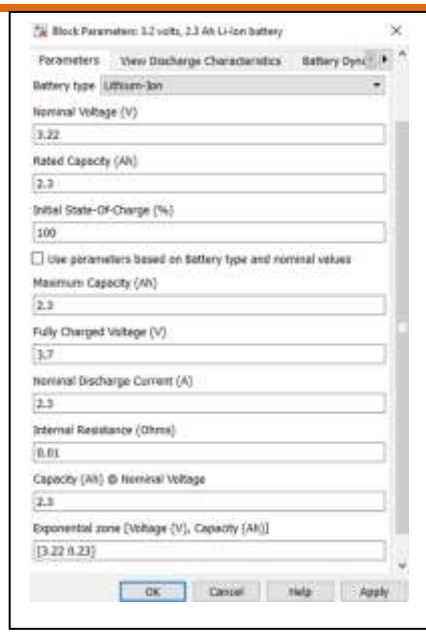

Fig. 8. *Li-Ion battery parameters[4].*

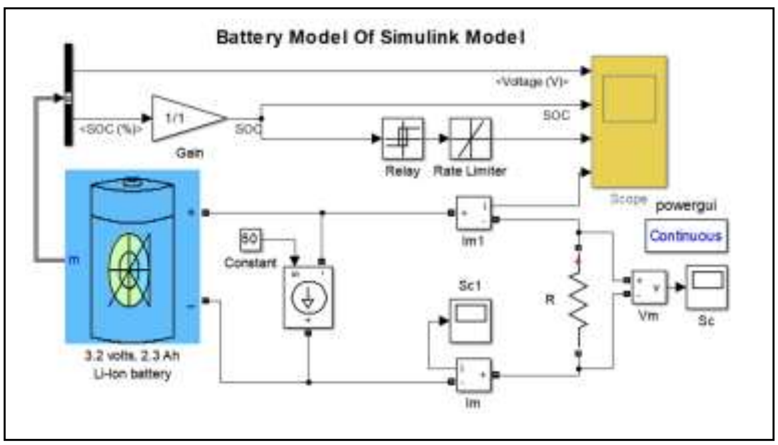

Fig. 9. *Matlab / Simulink Model of System.*

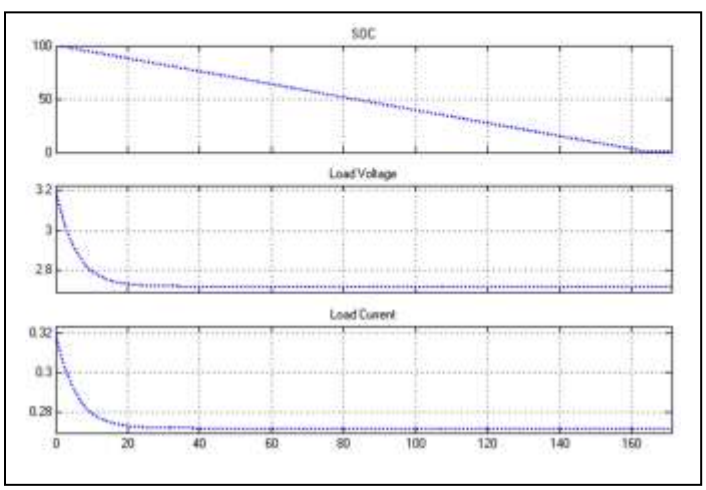

Fig. 9. *System results.*

5. Conclusion

In this study, for the dynamic model of the lithium-ion battery, because of the high performance and low processing density, the Thevenin equivalent circuit is chosen from the electrical circuit models. The dynamic battery model of the system is created in Matlab / Simulink environment. Accordingly, the possibility of observing the system performance without the need for experimental arrangement is presented. As important as the efficiency of the system is the use of energy in the right and place. For economic and social development and human life; reliable, cheap and clean energy supply today has become the most important problem. It is known that 1.3 billion people in the world still do not have the right to use energy [5]. Therefore, it is a necessity to draw attention to energy efficiency in every study again.

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