Electrical bicycle sharing scheme for medium-scale and large-scale organizations

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Abstract: ***This paper deals with the development of an Electrical Bicycle sharing scheme, in which we are discussing the availability of different types of Electrical Bicycles also about different components available for the development of Electrical bicycles. The proposed scheme uses a simple RFID (Radio Frequency Identification) card or Id-password based locking and unlocking as well as a prepaid charging system, in which time-based charges are fed from the user. Also, this paper discusses the Solar charging system for Electrical bicycles, calculation of the payback period for Electrical bicycles. Lastly, the different benefits of sharing scheme have been included.***

Keywords: Electrical Bicycle; RFID (Radio Frequency Identification); Arduino Mega.

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1. Introduction

Fast, easier and eco-friendly transport helps for the better growth of any small scale or large-scale organization. Due to this, there is a need for good transport in any institute or organization which leads to a tremendous requirement of vehicles mainly two-wheelers which will take a small area for parking and can give transportation facility at medium range of speed (20-40Kmph). For which two-wheelers fitted with IC engines of different capacities were used depending upon application basis. The main pollutants emitted from automobiles are hydrocarbons, Carbon monoxide, Sulphur dioxide, nitrogen dioxide and particulate matter. Large use of two-wheelers contributed to two-third of the pollution in major cities in India. The emissions levels are found to be higher at low speeds. Due to the higher traffic density, the average speed of travel in urban areas has come down between 20-40Kmph. To summarize, the usage of two-wheelers in urban regions is found more operating at lower speeds emitting higher level of pollution.

We can replace these low-speed application two-wheelers with Electric Bicycles. To limit the number of bicycles as well as control the power consumption and efficient use of bicycles we can implement Electrical Bicycle sharing scheme in premises of certain organization which may be small scale or large scale. Bicycles are cheap, clean and can reduce traffic problems making them a promising option for urban transportation. A person can ride a bicycle 2 or 3 times faster using the same energy that he would consume while walking. This feature makes the bicycle the most efficient as well as a nature-friendly vehicle [1]. Riding a bicycle has important benefits for human health. According to the WHO study, cycling 30 minute every day can increase human life by eight years [2].

However, cycling is not as comfortable as driving a car or riding a scooter making cycling less popular. Electric powered bicycles can help with an electric motor allowing the cyclist to travel longer distances and allow to easily climb road slopes. As Electrical Bicycles are giving same application as that of the mopeds which becomes more user-friendly and having less air pollution as well noise pollution. Also, Electrical Bicycles requires less maintenance as compared to any IC engine fitted vehicle. Seeing all this, today's number of electric-powered bicycles has been increasing rapidly.

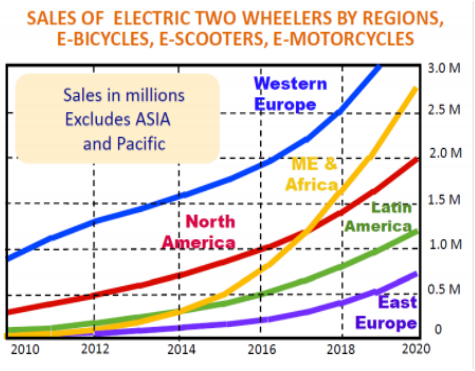

Figure 1: Sales evolution of the electric bicycles

Objective

Successful implementation of Electrical Bicycle sharing scheme in medium or large-scale organizations, which will help the organization for the development of transport system which is financially efficient also having reduced pollution in premises of an organization and is also user friendly. Use of solar-based charging stations to charge Electrical Bicycles, which will be an On-grid system so that organizations can get benefit from excess power generation.

Depending upon the mode of power delivery done by Electrical Bicycles they are mainly classified into two types:

- Power on demand
- Pedal Assist

1.1 Power on demand

In these types of Bicycles, the rider can change the power delivered by the motor manually by changing the throttle position. There are different types of throttles, depending upon mechanical construction. Commonly used throttle is the same as that of the accelerators in bikes or mopeds. They are fitted similarly as fitted in bikes or mopeds. The rider can easily control the speed as same as bikes or mopeds. In this type of Bicycles, the rider can:

1) Ride by using motor power only.
2) Ride by using pedals i.e., same as a normal bicycle.
3) Ride using both at the same time.

1.2 Pedal Assist

In this system, the rider has the power to engage the motor with the help of the "power on demand" system and on the other side, when the rider needs the power to reach its goal, the motor will automatically help to reach a certain speed without using the throttle and it is done with the help of "pedal-assist" system and this system is used in nowadays. These types of systems have a default PIC controller which controls the demand and electric output. It consists of normally two types Pedelecs and S-Pedelecs.

- *Pedelecs:* Sensors are fitted in such a way that the motor will provide power automatically to support the rider. In this mode, the motor can deliver maximum power up to 250 watts (maximum power limit in India for Electrical Bicycles without the need for registration).

- *S-Pedelecs:* have pedal-assist only, motor power can be greater than 250 watts, can attain a higher speed (e.g., 45 km/h) before the motor stops assisting, legally classed as a moped or motorcycle (not a bicycle).

2. Components Used in Electrical Bicycle

Following are the main components used in Electrical Bicycles:

- Motor
- Controller
- Battery Pack
- Throttle (depending upon the type of bicycle).

2.1 Motor

Mainly two types of motors are used in Electrical Bicycles: Brushed and Brushless. Different types of motors are available depending upon the requirement of torque and power. Numbers of verities of motors are available depending upon cost, complexity, type of drive (chain drive, hub motor, belt drive, friction drive, direct drive, geared motor drive). Different types of drives are available for electrical power-assist with pedals, but BLDC hub motors are the most popular and commonly used design. This type of motor is fitted in the wheel itself, in which stator winding is fixed at the axel while permanent magnets are rotating with the wheel. The bicycle wheel hub is the motor. Standard wattage of motor should be less than 250 watts in India (for non-registered bicycles), if the wattage is greater than 250 watts registration for such type of bicycles is made mandatory in India.

As the popularity of Electrical Bicycles is going on increasing in recent years, many countries have set legal limits on how motor power, speed, weight and engine support will be activated. The standards set by countries mainly depend on security approaches as well as the required performance of bicycles depending upon the application. Standards set by different countries are summarized in Table 1.

Table-1: Legitimate electric bicycle limits set in various countries [3]

Country/Region	Motor Power Limit [W]	Speed Limit [km/h]	Weight Limit [kg]	Others Limitation
European Union	250	25	No Limitation	Pedal Assisted
Britain	200	25	40	Pedal and on / off switch
Canada	500	32	No Limitation	Pedal, on / off button and maintain less than 4 wheels
Taiwan	No Limitation	30	40	No Limitation
Japan	No Limitation	24	No Limitation	No Limitation
China	240	20	No Limitation	No Limitation
America	750	32.2	No Limitation	Pedal, on / off button and maintain less than 4 wheels

Mainly Brushless DC motors are used because they have the following advantages over brushed motors:

- Higher torque to weight ratio.
- Increased torque per watt of power input (increased efficiency).
- Increased reliability.
- Lower maintenance requirements.
- Reduced operational.
- Less mechanical noise.
- Longer lifespan (no brush and no commutator erosion).
- No ionizing sparks from the commutator.
- Reduction of electromagnetic interference (EMI).

Limitations of BLDC motor are:

- Major limitation is the thermal withstanding of the permanent magnets.
- High power rating motors are not feasible because of Permanent magnets and their cost.
- Harmonic content in back EMF causes some torque ripple will occur at motor torque.
- The need for an electronic speed controller (ESC) to commutate the motor.

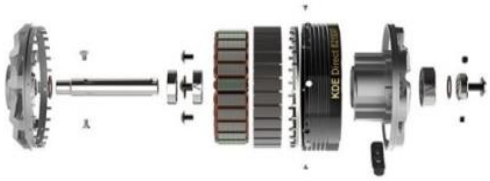

Figure 2: BLDC motor construction

For Electrical Bicycles, we can use DC series motor, PMDC motor, BLDC motor; the comparison based on power, speed and supply voltage is given in the Table 2 below:

Table-2: Comparison of different types of motors [4]

Parameters	Symbol	DC Series	PMDC	BLDC
Power	P	250	250	250
Speed	N	300	400	350
Voltage	V	24	24	36

2.2 Controller

In controller power electronics devices connected in such way that to control the supply given to stator windings in BLDC motor. Supply given to stator windings depends upon the position of the rotor which is sensed by sensors such as Hall sensor. Depending upon rotor position windings are energized so that speed control and proper commutation can be achieved. Min work of controller is to achieve speed control depending upon the rider requirements. As the throttle position changes speed should be varied. As the throttle position is changed depending upon that motor speed is varied by switching of power electronic devices. Besides that, the controller also performs the function of under-voltage protection, control power supply, over current protection and also drive BLDC motor. The below fig shows the schematic of the connection between throttle, controller, BLDC motor and power supply.

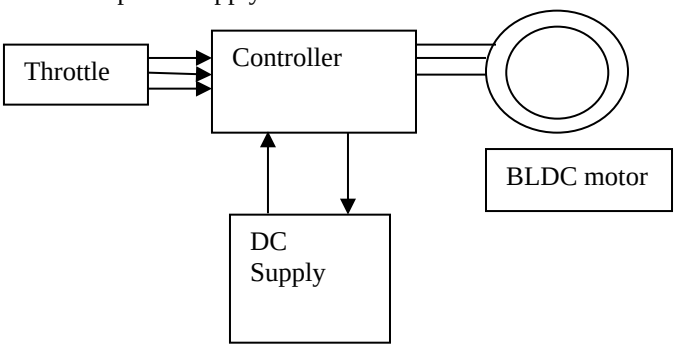

Figure 3: Connection Schematics

2.3 Battery Pack

In Electrical Bicycles rechargeable batteries are used. There are different types of rechargeable batteries are available such as Lead-acid, Nickel-cadmium, lithium-ion, LiFepo4 i.e., lithium iron phosphate (type of lithium-ion), Li-ion polymer, etc. Among these, all lithium-ion and lithium iron

phosphate (LiFepo4) batteries are normally used because they have greater energy density compared to others; also, they can be manufactured according to the requirement in different sizes and shapes. Table-3 gives the comparison between different types of rechargeable battery packs.

Table-3: Comparison between common rechargeable batteries.

Type	Lead acid	Li-ion	Li-ion polymer	LiFepo4
Gravimetric Energy Density (Wh/Kg)	30-50	110-200	100-130	90-160
Cycle life	200-300	500-1000	300-500	1000-10000
Fast charge time	8-16 hr	2-4 hr	2-4 hr	2-4 hr
Overcharge tolerance cell voltage	High	Very low	Low	Low
Internal Resistance (mW)	< 100 12v pack	150-250 7.2v pack	200-300 7.2v pack	150-300 7.2v pack

2.4 Throttle

Basically, throttles are the same as the accelerators used in automobiles for speed control. The throttle is used for manual control of the power delivered by the motor. Different types of mechanical design are available but the main objective remains the same. Some throttles are integrated with voltage indicator display and key controls sockets (fig. 4), low-cost simple throttles are available in the market (fig. 5) and also thumb throttle (fig. 6).

Figure 4: Throttles with voltage indicator

Figure 5: Low-cost simple throttle

Figure 6: Thumb throttle

3. Why sharing scheme?

As in any organization, different time schedules and shifts are followed. Members of organizations use transport systems for various purposes. If every member used their own transport vehicle of inter-organization transport number of vehicles will be great. Also, organizations will face different problems such as uncontrolled vehicle transport, increase in the air as well as sound pollution and many other problems. Organizations can deal with all these problems easily by a simple solution that is the implementation of sharing scheme. To reduce pollution emitted by IC engine-based automobiles we can replace them with Electrical Bicycles depending upon the application.

4. Electrical Bicycle sharing scheme

In any medium-scale or large-scale organization, there is a requirement for a transport facility for organizational members. To make fast and pollution-free transport between different departments we can use Electrical Bicycle. Electrical Bicycles are as same as moped bikes in application but with a maximum speed of up to 30 Km/hr. For implementing the sharing scheme, we can use two different methods for locking and unlocking of bicycles namely:

- RFID based system
- User Id-password based system

4.1 RFID based system

In RFID based system each user will be provided with a personal identity card that stores user data such as user name/unique Id and balance. The user has to pay charges to the organization for the ride which will be depending on a time basis. Charges will be deducted from the user personal identity card. To take a ride user should recharge his/her identity card from the recharge machine. By using a personal identity card user will be able to unlock the bicycle for the ride. To make this locking and unlocking system, components are required such as Arduino mega, relays, solenoid lock, LCD display, Dc to Dc converter (give power supply to Arduino, relay and solenoid lock) and an RFID module.

RFID module system consists of mainly two components- transponders/personal identity card given to the user and the data reader. The reader generates a high-frequency electromagnetic field by using a radio frequency module and antenna. Whereas a personal identity card is a passive device i.e., do not have any power supply. A personal Identity card consists of a small chip that processes and stores data, antenna which transmit and receive data. For reading or writing data on an identity card it is placed near the reader it does not mean that it should be in a straight line with the reader. As the reader generates an electromagnetic field, this powers up the antenna and chip of the identity card. Powered chips send data to the reader in the form of another radio signal. Now, this data is sent to the microcontroller (Arduino) by the reader. Here we can use the RC522 RFID reader module which creates 13.56 MHz of magnetic field. The reader can communicate with the controller at a speed of 10 Mbps by using the 4-pin serial peripheral interface (SPI).

As soon as any user put his/her own personal identity card near the reader, the reader will read the data from the card and send it to Arduino. Arduino will process the data as per the program. Program flow is shown in the below fig. 7.

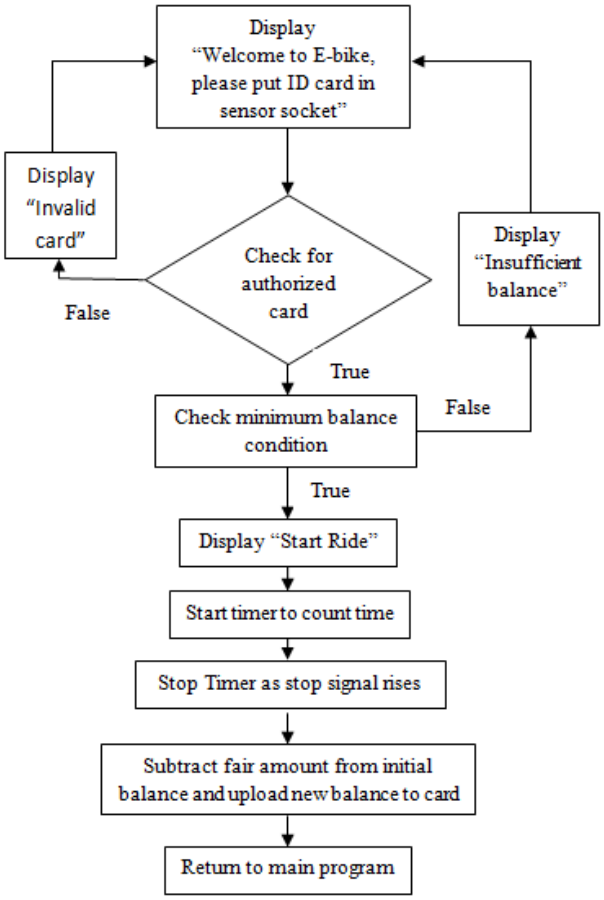

Figure 7: Program flow diagram of the locking-unlocking system

In RFID based system, users have to put their personal Identity cards in the socket provided near the reader. When the ride gets complete as the user presses the stop button, the ride will end. Depending upon fair policy by the organization amount will be reduced from the prepaid balance. As ride time increases fair amount also increases as the user reaches to minimum balance criteria defined by the organization warning will be given and the user has to stop the ride as early as possible otherwise some predefined charges will be reduced from the user account on the next recharge.

A separate recharge machine will be given to the organization. The recharge machine uses Arduino, keypad, LCD display and an RFID module. By collecting the amount manually from the user, the recharge machine manager will be able to recharge user cards. Process of Recharge will be simple - manager will have to enter the personal security code given, then insert user's personal identity card in reader socket, followed by entering the recharge amount. Program flow is shown in below fig. 8.

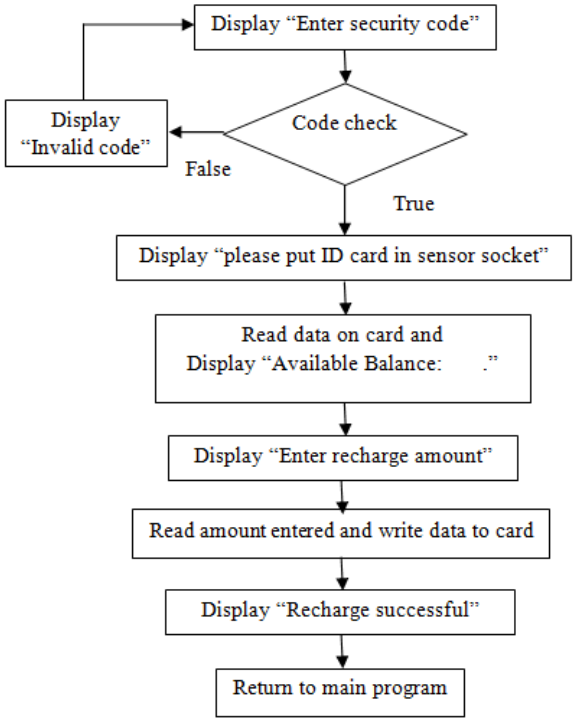

Figure 8: Program flow diagram of recharge system

4.2 User Id-password based system

RFID based system and user id password system are nearly the same instead of using the personal identity. In this system, a unique id and password are given to every user. Users have to enter his/her Id and Password to take the benefit of the ride. The benefit of this system is, it is economical than RFID based system whereas the disadvantage is it is time-consuming than RFID based system also less user friendly. Program flow for both systems is the same. Below fig. 9 shows the simulation diagram for the user Id-password based system.

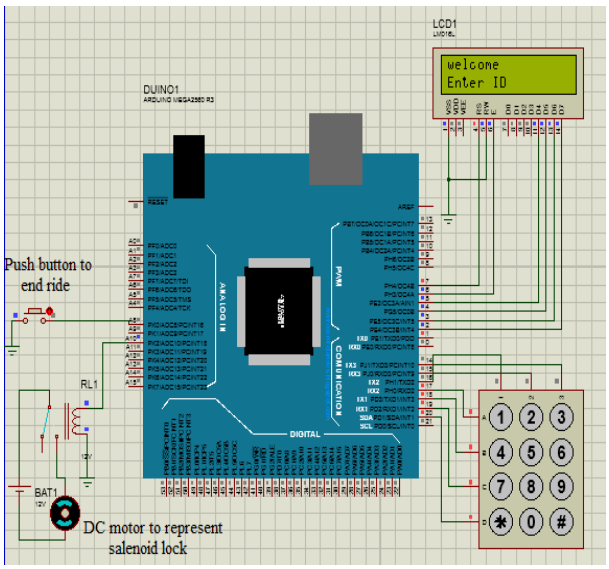

Figure 9: Simulation diagram for user Id – password-based system

5. Charging and parking stations

Depending upon the requirement of the organization, a charging and parking station will be provided. At the end of the ride, it will be compulsory for the rider to park an Electrical bicycle in a given parking area. At the same place of parking charging facilities are also provided. The power supply required for the charging will be provided by using the solar-based system. The number and size of charging and parking station will depend upon the area of organization, rate of transportation and number of Electrical Bicycles. To encourage users for putting on power supply given to bicycles special incentives (Depending on organizational policies such as 5% off on fair cost, etc.) can be given.

6. Certain assumptions are done for calculation of the payback period

i. Charges per unit of electricity are Rs. 6. (For non-domestic greater than 50 kW).

ii. Charges for the ride per hour are Rs. 15.

iii. Maintenance cost Rs.1000/year

iv. The cost of an Electrical Bicycle including locking-unlocking system is Rs. 22,000/-.

v. Specification of BLDC hub type motor: 250w, 36v. Battery capacity: 8Ahr.

vi. The average speed of a bicycle 18 Kmph.

vii. 2 times full use of battery per day (i.e., charging up to a maximum limit and using up to a minimum limit for 2 times a day)

viii. Single charge run of bicycle 28km (To run constantly at a maximum speed of 25kmph for 1-hour battery capacity should be 7Ahr as the battery capacity of a bicycle is 8Ahr it can travel 28km in single charge)

ix. Electricity charges as per Maharashtra state electricity distribution company limited for LT II:LT Non-domestic such as fixed charges-Rs.150/month, Fuel adjustment charges- Rs.0.61/U, wheeling charges-Rs.1.25/U, Electricity tax/duty- 16% of bill.

Now the average speed of a bicycle is 18 kmph, so it can travel for 1.5 hr in one charge.

Rent charges for the day will be
= (1.5 × 15 Rs./hr) × 2 = Rs. 45/day.

For a month, it will be
45 × 30 = Rs.1350
[As 2 times full use of battery is assumed]

To charge battery of 36V and 8 Ahr, required energy will be = 36 × 8 = 288 Whr.

Charging of battery about 2 times a day so,
288 × 2 = 576 Whr per day.

Total consumption for a month will be,
576×30=17280 Whr per month

Charges for required energy as per Rs. 6/ U
17.280 × 6 = Rs. 103.68

Now dividing maintenance cost of Rs.1000/yr into per month basis, it will be,
1000 / 12 = Rs. 83.33/month.

Total electricity bill considering all charges
= 103.8 + 150 (fixed charges) + 10.54 (fuel adjustment charges) + 21.6 (wheeling charges) + 45.75 (electricity tax)
= Rs. 331.69

Net earnings per month will be,
= Rs. (1350 - 331.69 - 83.33) = Rs. 934/month.

So, payback period will be,
Payback period = 22,000 / 934
= 23.55 months = 2 years (Approx.)

7. Conclusion

This paper deals with how a successful sharing scheme of Electrical Bicycles can be implemented in any medium and large-scale organization. Sharing scheme supports to reduce the traffic, control several vehicles as well as to reduce the pollution. Electrical Bicycles are one of the user-friendly as well as nature-friendly modes of transport.

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