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# Developing a Hybrid Electric Bicycle

**Rejo Roy[1], Albert John Varghese[2]**
[1,2]Asst. Prof., Electrical Engg., Rungta College of Engg. & Tech, Bhilai (C.G.) India.

**ABSTRACT**
*Energy and environmental concerns, new paradigms for urban mobility and transportation increased in the past few years. The interest in Light Electric Vehicles has been catching up rapidly. Electrically Power Assisted Cycles or electric hybrid bicycle received a great deal of attention as it proves ease to the rider while riding. Electric hybrid bicycle is one that is suitable for general-purpose commuting. Electrically Power Assisted Cycles enables substantially longer distance power assist cycling. Several efforts have been made in order to improve its performance in terms of autonomy, weight, aesthetic and feeling with the rider. In this paper, hybrid electric bicycle developed by a team of engineering students as a part of their project is presented. The paper gives the methodology adopted, selection criteria of various components, their specifications and performance of the developed bicycle.*

***Key Words:*** BLDC Hub Motor, DC-DC Converter, Hybrid Electric Bicycle, Lithium Iron Phosphate Battery

## I INTRODUCTION

1895 saw the first US patented electric bike but the first production of electric bikes was witnessed in early 90’s. However, they did not gain much attention but it did spark big bicycle manufacturers to start developing bikes of their own. Initial electric bicycles were unbelievably heavy and less efficient. Nowadays mass production of electric bicycles is done by Hero, Revolt, Ola, TVS, Ather, Bajaj, Okinawa and many more in India.

Some of the key points based on the literature review carried out are highlighted as below:

- V. Thiyagaranjanet al [1] summarized that the BLDC motor for the electrical bicycle is of the quality 3 section tetragon kind, usually rated at some hundred Watts and therefore the battery voltage is typically 36V or 48V counting on the circuit current.
- DainisBerjoza et al [2] conducted a research so as to settle on a correct charging device, to optimally load the electrical wiring network likewise on opt for power and alternative parameters for energy devices so as to confirm the charging method.
- VidyadharGulhane et al [3] have discussed about choice of batteries, choice of electrical motors for specific capability vehicles, style of controllers, style of battery. They have emphasized basic details concerning characteristics of varied motors and controllers used for battery operated electrical vehicles.
- Matteo Corno et al [4] discussed about traffic congestion, energy, and environmental considerations as factors boosting the interest for light electric vehicles. They concluded that electrically power-assisted cycles (EPACs) have great potential as they are cost effective, safe, easy to use, and have a small footprint.

The Hybrid Electric Bicycle was implemented by a team of UG students (Pallav Chatterjee, Abhishek Kumar Urwasha, Mohan Kumar, Jayant Tandan) of Electrical Engineering from Rungta College of Engineering and Technology, Bhilai. The conversion of a normal bicycle into a hybrid electric bicycle and the process of planning, implementing, and testing a Hybrid Electric Bicycle is presented in this paper.

## II HYBRID ELECTRIC CYCLE

A hybrid electric bike is a just like a normal bike but equipped with an electric motor that gives you additional power to your pedaling action. This can help you get some exercise or move around quicker and more comfortably. Electric hybrid bicycle also work well for commuters who aren't pressed for parking space and want a little assistance when cycling to work. A basic electrical bicycle runs on a BLDC motor, is powered by batteries and controlled from an electronic unit.

A very basic block diagram of a hybrid electric bike is as shown in Fig. 1which shows the basic speed control and the transfer of power.

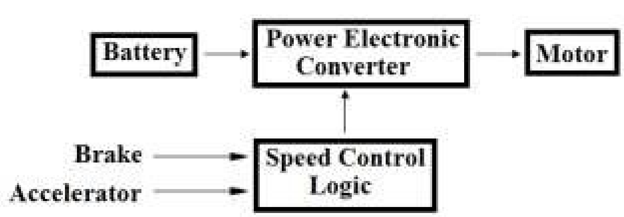


**Fig 1: Block Diagram of a Hybrid Electric Bicycle**

Hybrid electric bikes can be operated in three modes as given below:

- Pedaling manually
- Electric motor driven
- Hybrid mode i.e., simultaneous manual pedaling assisted by electric motor

The advantages of hybrid bikes over conventional bicycles are:

- Less effort is required; whether it is for leisure or commuting,
- Travel further, faster and carry heavier loads

Hybrid Electric bicycles are capable, versatile, cheap to run and offers manual exercise as a fringe health benefit.
The biggest disadvantages of Electrically Power Assisted Cycles (EPACs) are:

- The need of periodic recharging the battery
- Increased loading of bike due to the electric motor and associated components

The distance hybrid electric bicycle will get on full charged battery is dependent on a multitude of factors like:

- Topography (Road condition, geography, weather conditions etc.)
- Level of assistance
- Condition of tyres
- Load being carried

## III METHODOLOGY

To design a capable hybrid electric bicycle, which maintains the characteristics similar to that of a conventional bicycle and provides pedal assist? The steps involved in the creation of hybrid electric bicycle are as listed below:

- Calculation of electric motor power
- Selection of Motor
- Selection of Controller for Motor
- Selection of DC to DC Converter and speed control
- Selection of Battery and Charger
- Specifications of Components required

The various steps are described below:

**(a) Calculation of Motor Power output**

Table 1 provides the calculation of tractive force and motor power requirement for the hybrid electric bicycle for a speed of 35 km/hr. and to carry a total weight of 200 kg.

**Table 1**
**Calculation of Tractive force and Motor Power Requirement**

<table>
<tr><td colspan="3">Tractive force = $F_{rolling} + F_{gradient} + F_{drag}$</td></tr>
<tr><td>Rolling force</td><td>Force to climb gradient</td><td>Force to overcome aerodynamic drag</td></tr>
<tr><td>$F_{rolling} = C_r*m*a$<br>Where,<br>$C_r$ → coefficient of rolling resistance (depends on road)<br>m → mass of vehicle (kg)<br>a → acceleration due to gravity ($m/s^2$)</td><td>$F_{gradient} = mg*Sin\theta$<br>Where,<br>m → mass of vehicle (kg)<br>g → acceleration due to gravity ($m/s^2$)</td><td>$F_{drag} = 0.5*e*v^2*C_A*A_f$<br>Where,<br>e = density of air medium = 1.23kg/$m^2$( for air at sea level)<br>v = velocity of vehicle (m/s) = 9.72 m/s<br>$C_A$ = Coefficient of air resistance = 0.88<br>$A_f$ = frontal area of vehicle</td></tr>
<tr><td>Lets assume,<br>$C_r$ =0.01(for normal road)<br>m =200 kg<br>a = 9.81 $m/s^2$ (g)<br>$F_{rolling}$ = 0.01*200*9<br>= 19.6 N</td><td>For flat surface θ = zero<br>$F_{gradient}$ = 0 N</td><td>$A_f$ = height*width*adjusting value<br>Width → length of handle bar =500mm<br>Height → ground to person helmet =1500mm<br>(Adjusting value normally assumed to be 70% for bike)<br>$A_f$ = 1.50*0.50*0.70<br>= 0.525 $m^2$<br>$F_{drag} = 0.5*1.23*(9.72)^2* 0.88*0.525$<br>$F_{drag}$ = 26.84 N</td></tr>
<tr><td>Power required to overcome rolling resistance</td><td>Power required to climb gradient</td><td>Power required to overcome air resistance</td></tr>
<tr><td>$P_{rolling} = F_{rolling}$*vehicle velocity (m/s)= 19.6*9.72 = 190.51 Watts</td><td>$P_{gradient}$ = 0 Watt</td><td>$P_{drag}$ = 26.84*velocity of vehicle in m/s = 26.84*9.72= 260.88 Watt</td></tr>
<tr><td colspan="3">Power needed for motor = $P_{rolling} + P_{gradient} + P_{drag}$<br>= 190.51+0+260.88<br>= 451.39 Watt<br>Max. power = 450 Watt (approx)</td></tr>
</table>

**(b) Selection of Motor -** The normal bicycle can be converted into electric bicycle by assembling on it DC motor, BLDC motor etc. Here a brushless DC electric motor (BLDC motor), also known as an electronically commutated motor is used. It uses an electronic closed loop controller to switch DC currents to the motor windings producing magnetic fields which effectively rotate in space and which the permanent magnet rotor follows. The controller adjusts the phase and amplitude of the DC current pulses to control the speed and torque of the motor. This control system is an alternative to the mechanical commutator (brushes) used in many conventional electric motors. Fig 2. shows the BLDC Hub Motor used in the hybrid electric bicycle.

**Fig 2: BLDC Hub Motor**

**Fig 3: Controller**

**(c) Selection of Controller for Motor -** The controller is an important component as it decides the rotation of the BLDC motor. The built in hall sensors in a BLDC motor helps in judging the rotor position and the controller in turn acts in tandem to give a proper control of the BLDC motor rotation. A BLDC motor controller regulates the speed and torque of the motor; it can also start, stop, and reverse its rotation. In a BLDC motor commutation happens electronically with the help of transistor switches. The sensors measure the rotor's position and send out this data. The controller receives the information and enables the transistors to switch the current and energize the required winding of the stator at the right time. Fig. 3 shows the controller used in the hybrid electric bicycle.

**(d) Selection of DC to DC Converter and speed control -** As the battery gives a DC output and the DC motor. A DC-to-DC converter matches the battery DC voltage with the motor DC voltage. A DC-to-DC converter is an electronic circuit or electromechanical device that converts a source of direct current (DC) from one voltage level to another. It is a type of electric power converter. Fig. 4 shows the DC to DC converter used in the hybrid electric bicycle.

The feedback from the person (rider) using the hybrid electric bicycle is important and helps in real-time feedback during the driving state. Throttle and Brakes helps in deciding the firing angle of the power electronic switches used in the DC to DC Converter. Throttle helps in increasing the speed of BLDC motor while the brake helps in cutting of the power to the BLDC motor. Brakes are also connected to the brake shoe for better braking performance. Fig 5 shows the throttle, and Fig 6 shows the brakes fitment used in the hybrid electric bicycle. This in turn helps in varying the amount of power delivered to the BLDC Motor.


**Fig 4: DC to DC Converter**

**Fig 5: Throttle**

**Fig 6: Brakes**

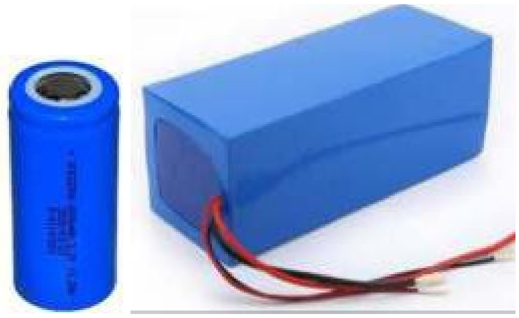

**Fig 7: Battery Pack**

**(e) Selection of Battery and Charger -** Because of low cost, high safety, low toxicity, long cycle life and other factors, Lithium Ion Phosphate batteries are finding application in vehicles, utility scale stationary applications, and backup power. Lithium Ion Phosphate batteries are cobalt-free.

When a battery is connected to an external electric load, a redox reaction converts high-energy reactants to lower-energy products, and the free-energy difference is delivered to the external circuit as electrical energy. The battery used is Lithium Ion Phosphate type. The lithium iron phosphate battery ($LiFePO_4$ battery) is a type of lithium-ion battery using lithium iron phosphate ($LiFePO_4$) as the cathode material, and a graphitic carbon electrode with a metallic backing as the anode. Fig. 7 shows a battery cell and battery pack used in the hybrid electric bicycle.

A wall mounted battery charger is used for the charging purpose. A battery charger is a device that stores energy in a battery by flowing an electric current through it. The charging protocol (how much voltage or current for how long, and what to do when charging is complete) depends on the size and type of the battery being charged. The charger may have temperature or voltage sensing circuits and a microcontroller to safely adjust the charging current and voltage, determine the state of charge, and cut off at the end of charge.

**(f) Specifications of Components required -** The specifications of the various components used in the hybrid electric bicycle are tabulated in Table 2.

**Table 2**

**Components used and it's Specification (may mention makes/model nos. also???)**

| S. No. | Components | Specification | Quantity |
|---|---|---|---|
| 1. | Brushless DC Hub motor | 350W, 36V<br>Max Power: 500 W | 1 |
| 2. | Motor Position Controller | 36V | 1 |
| 3. | DC to DC Converter to feed DC motor | 36 V to 12 V | 1 |
| 4. | Pedal assets | - | 1 |
| 5. | Battery | 36V, 12Ah | 1 |
| 6. | Battery charger | 43V | 1 |
| 7. | Key lock with digital volt meter | - | 1 |
| 8. | Head light, Horn | 12V | 1 |
| 9. | Electric throttle | - | 1 |
| 10. | Cut off brake | - | 1 Pair |
| 11. | Cables | Copper | - |
| 12. | Conventional Bicycle | - | 1 |

## IV ASSEMBLY OF HYBRID ELECTRIC BICYCLE

Initially the BLDC Hub Motor is mounted on the rear wheel in between the spokes and gear for chain mounted on the rear wheel on the motor shaft. The chain is connected with the pedal gears. The electrical connection is done for power transfer to the motor using a DC-DC power converter in between battery and motor. Motor Controller is responsible for maintaining the rotation of the Motor. Brake and throttle is used for deciding the speed of travel i.e., rotation of the motor. A battery charger is used from the wall socket and used for charging the battery.

The concept of the project is providing ease to the rider while riding a bicycle. Rechargeable battery is used with long life for charging. BLDC hub type electric motor is also used in this project. The hybrid electric bicycle is a project that can promote both cleaner technology as well as a reducing dependence on oil. It will run on clean electric power with the ability to recharge the battery. The final hybrid electric bike is shown in Fig 8.


**Fig 8: Hybrid Electric Bicycle**

The system here is tested and it is observed that it is capable of maintaining the battery charge and improvements can be achieved for urban cycling. An electric hybrid bike with minimal additional weight, a speed control system based on the decision-making of the rider (i.e., using throttle and brake) and microcontroller. This is capable of greater efficiency and various other feedback control mechanisms compared with typical hybrid bikes is implemented.

The project has been completed at cost of Rs. 18000/- which includes the cost of conventional bicycle. The basic cost of a hybrid electric bicycle in the market is around Rs. 24,000/-.

## V RESULTS AND DISCUSSION

The growing demand of consumers for non polluting modes of transport is growing each day; this project will help in addressing this issue. The hybrid electric bicycle was designed keeping in mind the mechanical and electrical safety and considerations. It proves to be user friendly and easy to handle.

Some of the noteworthy points to be highlighted about the Hybrid Electric Bicycle during various phases of its testing (carried out by project members) as shown in Fig 9 are as given below:

- It could carry two people comfortably (also tested with load on carrier of the bicycle)
- It could travel a distance of 30 – 35 km on average with single charging
- The working was very smooth and noiseless
- There were no vibrations or jerks
- The components did not report any abnormal heating
- It could work even in rainy days, and short circuits were not detected (i.e., water poured on battery, controller, motor etc.)
- takes half unit of energy to charge the battery fully
- It can travel at a maximum speed of 40 km/hr

**Fig 9: Hybrid Electric Bicycle (during testing phase)**

## VI CONCLUSION

The hybrid bike powered by dual source, pedaling and electricity powered BLDC Hub Motor. Compared to Internal combustion based bikes, hybrid electric bicycle is more efficient and economic. For environmental safety & protection use of electric vehicle instead of internal combustion engine vehicle is preferable. Use of electric vehicle reduces the noise pollution. The hybrid bike offers an eco friendly and cost effective solution to the high cost fossil fuel derived petrol.

Lithium Iron Phosphate battery helps in improved battery life of almost 7-8 years which will reduce the maintenance cost of the hybrid electric vehicle and it will help in reducing the cost of maintenance over time. Here electric propulsion system using BLDC motor with sensor speed control along with Smooth running operation is demonstrated and in future, a project may be taken for sensor less operation to economize the cost of hybrid bicycle. The solar PV charging of battery may also be considered in a future project. The cost can be reduced substantially due to economies of scale with large scale production to facilitate its purchase by economically weaker section of society.

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