Design and implementation of low-cost electric bicycle with battery level indicator

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Abstract. In the recent days, carbon emission from the vehicles are found to increase the level of air pollution in a huge manner. In order to reduce the pollution due to transportation, electric vehicles are seen as an alternative. This approach paved way for developing an electric bicycle by incorporating 250 W BLDC hub motor, 295.6 WH lithium-ion battery and pedal assist system (PAS). The maximum speed of the bicycle is 25 km/h. The distance covered using PAS is 75 km. The maximum carrying capacity is 120 kg with a charging time of 2.5 to 3 hours. The pedal assisting system helps to share the torque between manual pedalling & electric motoring. This ensures that the battery is used in an efficient manner. The cost of this bicycle includes cycle assembly, battery, hub motor, controller circuit and wireless odometer. The total expenses involved in developing this prototype is nearly 38.57% lesser without profit when compared to other products available in the market. The pulling capacity of the cycle can be enhanced by increasing the battery capacity which would add additional cost based on capacity.

Keywords: Lithium-ion, Pedal assist system, Transportation, Battery level indicator, Hub motor

1. Introduction
As we move towards the decade's end, a ton's evolving. The purchaser notions to auto organizations' standpoint to vehicles in India, there's a ton occurring in this area. Indeed, the legislature is attempting to acquire electric vehicles to India and actualize it by 2032. However it would appear that India will require more opportunity to acclimate to this change. Electric vehicles and Hybrid vehicles are the discussion of town in view of decreased outflows, yet additionally in light of the fact that they give the proprietor a status in the public eye, that of one aware of nature, a green crusader of sorts.

E vehicle is very useful in our country, because in this way electric bicycle was designed and developed successfully [1-2]. Features of this vehicle are 250W BLDC hub motor, 295.6WH lithium-ion battery, pedal assist system (PAS), maximum speed 25 km/h, range by using the PAS is 75 km in single charging, maximum carrying capacity 120kg, and charging time 2.5 to 3 hours. The pedal assisting system helps to share the torque between manual pedaling & electric motoring. So that, battery is used in efficient manner [3-5]. The cost of this cycle includes the price of the cycle assembly, battery, hub motor, controller circuit, wireless odometer, etc. The total expenses involved in developing this prototype is Rs.21,500/- which is nearly 38.57% lesser without profit when compared to other products available in the market.
The pulling capacity of the cycle can be enhanced by increasing the battery capacity which would add additional cost based on capacity. The decrease of air contamination should be possible by advancing the utilization of electric bicycles [6-8]. An electric bike also known as an eco-accommodating bi-cycle assimilated with electrically powered appliance is mainly preferred. There are huge number of e-bicycles reachable all over the globe in which only a few cases tend to assist the rider’s ability in pedaling the bicycle [9-11].

There are enormous kind of e-bicycles which are legally named bikes or mopeds [12-14]. When we focus upon the activity and accreditation of the incredible bikes such as electric cruisers [15], there are several laws which tend to exclude them throughout the process. There is a clear statement through electric bike laws that the e-bicycles are categorized self-sufficiently.

2. Methodology

The e-bicycle has been developed by incorporating the BLDC hub motor through hall sensor feedback. The user interface provides an opportunity to handle throttle and PAS with the control of signal line, control line and power line. The appropriate power source is provided to the experimental unit. This paves way for development of e-bicycle with enhanced efficiency. Figure 1 shows the schematic sketch of the proposed e-bicycle.

![Schematic sketch of the proposed e-bicycle](image)

The BLDC motor gets the position of the sensor and feed the sensor output to the controller. The controller gets the variable voltage from the throttle and drives the motor accordingly to the variable voltage with the help of the battery connected to the controller. The pedal assist sensor (PAS) helps the person to pedaling by driving the motor.

3. Design, development and implementation

3.1 Calculation of power required to traction

The mathematical steps involved in the proposed work to calculate the power required to traction through the basic concept is given in equation no. 1.
\[ F = m \times a \ (N) \] (1)

As we know, the value of mass ‘m’ is 150 kg. In this scenario, the maximum mass is assumed for carrying out the work. The value of acceleration ‘a’ is assumed as 6.94 m/10s. The force is calculated in equation no. 2. Here, the value of wheel diameter is 6". The torque is calculated using equation no. 3.

\[ \text{Force} = 150 \times 6.94 \times 10 = 104.1 \ N \] (2)

\[ \text{Torque} \ T = r \times F \ Nm \ r = \text{radius} \] (3)

Thus, the below mathematical steps will provide the power required for the wheel of bicycle. It is calculated using equation no. 4. The wheel radius is \( 262 = 13 \text{ inch} = 0.3302 \ \text{m} \).

\[ \text{Torque,} \ T = 0.3302 \times 104.1 = 34.373 \ \text{Nm} \]

\[ \text{Power,} \ P = T \times n \ W \]

\[ \text{Power,} \ P = 34.373 \times 6.94 \text{ cycle} \] (4)

\[ P = 238.548 \ \text{W} \]

It is almost 250 W power required to the center of the wheel of bicycle.

### 3.2 Selection of motor

There are various types of motor used for Electric vehicles applications. But among them BLDC motor and DC motor are best suitable for low power applications in terms of cost, size and weight. Hence the comparison between BLDC motor and DC motor is mentioned in Table 1.

|               | BLDC Motor                      | DC Motor                       |
|---------------|---------------------------------|--------------------------------|
| Efficiency    | 85% - 90% Efficient             | 75% - 80% Efficient            |
| Maintenance   | Low maintenance                 | High maintenance              |
| Noise         | Noiseless                       | Comparatively noisy           |

From the comparison, the BLDC motor is efficient and suitable for the E-Cycle. Usually the BLDC motors have hall sensors which is used to detect the position of the poles inside the motor. The position of the poles is sent to the controller through digital signals to the motor controller. The controller sends the signals to energize the respective rotor poles.

### 3.3 Selection of battery

There are many type of batteries available in market. The most commonly used batteries used for automobiles are Lead acid batteries and Li-ion batteries. The comparison between those batteries are mentioned in Table 2.

|                      | Lead acid battery | Li-ion battery               |
|----------------------|-------------------|------------------------------|
| Energy density       | Low               | High                         |
| Specific energy      | Comparatively low | Comparatively high           |
| Temperature sensitivity | Degraded significantly above 25°C | Degraded significantly above 45°C |
| Depth of discharge   | Around 50%        | Around 80%                   |
| Self-discharge       | High              | Very low                     |
| Size and weight      | Large and Comparatively heavy | Compact and Comparatively light |

From the above table the Li-Ion battery seems to be compact and power efficient. Hence Li-Ion batteries are used in this e-bicycle.
3.4 Technical specifications
The model that has been designed comprises of specifications as follows: 250 W BLDC hub motor, 295.6 Wh lithium-ion battery, maximum speed 25 km/h, maximum carrying capacity 120 kg, charging time 2.5 to 3 hours. The charger used is 42 volt, 2A, range 75 km in a single charge. It is attached with pedal assisting system battery level indicator (displays voltage, current and power consumed).

3.5 Selection of controller
The BLDC motor controller is a gadget used to drive the motor. It acts as an intermediate between the motor and the battery. The BLDC motor actually works on AC voltage. The controller converts the DC voltage from the battery to the AC voltage with the help of power electronic switches. The variable voltage is received from the throttle and thus the motor speed is controlled. The various input and output are mentioned below.

- Electrical brake pin
- Throttle pin
- Motor pin
- Battery pin
- Hall effect pin

3.6 Influence of electrical brake pin
If the brake is applied in the vehicle, mechanically the wheel is stopped. But the motor is not electrically stopped. This may damage the coils of the motor. So the electrical brake pin is used. The brake pin is connected to the brake lever. So when brakes are applied automatically the supply to the motor is also stops. This protects the motor coil damage.

The throttle pin is used to get the variable voltage signals to vary the speed of the motor. Motor pin is connected to the motor to drive the motor accordingly to the throttle signal pulse. Battery pin is connected to the battery with which the controller operates. Hall-effect pin gets the signal pulse from the hall sensors in BLDC motor and runs the motor. The wattmeter is used to measure the power consumed by the cycle when operated. The wattmeter is connected across the battery and the motor controller.

![Developed model of e-bicycle](image-url)
The Figure 2 shows the electric bicycle which has been implemented with all the necessary specifications. The test-run of the electric bicycle also provided good user experience and extreme comfortness.

4. Conclusion
The electric bicycle is one of the emerging technologies and it has been launched by so many reputed firms. Due to the reduction in fossil fuels like petrol and diesel, etc., the usage of electric vehicles will get increased in the near future. The use of proposed electric bicycle would reduce the greenhouse gas emissions from automobiles in the atmosphere in a considerable manner. The tool is also simple to manage and it is not much expensive. There are many technical features, such as, odometer, electrical and mechanical braking system pedal assist, hall-effect sensor provided in this unit which can make the electrical cycle smoother compared to other two wheelers.

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