Design and fabrication of solar powered bicycle

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Abstract. The paper focuses on the design of an electric driven bicycle that can stimulate power using solar energy and the rear wheel is provided with motor. The vehicle is being designed to house one driver; essentially, there would be need for additional space for other passengers and materials. In India, the pollution rate caused by fuel-consuming vehicles is very high. It is necessary to reduce the consumption of fuel/ use of fuel consumption vehicle and its hazardous emissions. The sunny weather in India lasts around 9 months, hence solar powered bicycle seems to be appropriate in India. Solar powered bicycle can become an alternative to the fuel consuming bikes and scooters.

1. Introduction

The exhausting stashes of paleontological fuels have made researchers and technocrats to seek for sources based on conventional and non-conventional energy forms. Additionally, the conservational deterioration owing to the burning of fuel is fearsome and substantiates the design of biodegradable system. Availability of solar energy in India is quite high. The wide-ranging mode of transference for local trip (for a range of five kilometers) is an electric bicycle. A solar operated bicycle is inexpensive, fittest and ecological but poses difficulties in climbing terrain [1].

Solar powered bicycle runs on electrical energy of battery to run the hub motor which eventually runs the bicycle [2].

2. Literature Review

According to Mayur Parmar et al.[1], a solar powered bicycle runs at an average speed of fifteen kilometre per hour and the maximum speed is twenty five kilometre per hour with the help of pedalling. They have accentuated that, the battery is charged in twofold manner and also with the help of solar or electrical energy. Their findings also show that the cost of solar powered bicycle is less Rupees Twenty thousand. They concluded that solar powered bicycles are Eco – approachable with negligible pollution.

Kartik S Mishra et al. [2] developed a solar hybrid bicycle. They have found that Hybrid bicycle conglomerates with the use of solar energy and a dynamo. Also they have concluded that, the solar hybrid bicycle can become a very cardinal alternative to the fuel operated automobile and hence its production is essential.
Prabhu Randhir et al. [3] designed and upgraded the regular bicycle and made it more efficacious. The bicycle is the combination of electrical energy and pedal operated. They revealed that the required power and the no load speed of the bicycle is 391.61 watts and 20.66 Km/hr respectively.

A. Muetze et al. [4] evaluated the performance of electric bicycles with important parameters. The parameters considered in their study are trends and regulations in market, attracting the customers by improving the designs and reducing the weight of the product.

According to A Karthi et al.[5], the most vibrant characteristic of the electric bike is that it does not use fossil fuels and pollution is reduced. Secondly, it is pollution free, sustainable and soundless in process. It can be charged with the assistance of adapter using alternating current. They concluded that the operating cost of the electric bike is low and further the cost can be reduced by mounting solar panel. Also they found that dis-assembling and maintenance of such bike is easy as it has less number of components.

Fabian Fogelberg [6], performed energy calculations on solar powered E-bikes. The study revealed that by placing 0.2-0.8 m² solar panels per bike on the station's rooftop will supply sufficient energy and also increasing the solar panel area, increase in electric energy production can be seen.

According to Göran Smith et al. [7] pollution is reduced and energy consumption is low in e-bikes. They also revealed that by introducing e-bikes large amount of energy can be saved and dependency on fuelled vehicles can be reduced.

According to Dr. K. Hema Latha [8], solar powered vehicles are pollution free and solar energy is abundantly available. The product cost is relatively cheap and the design and construction is simple. She concluded that with fully charged the range is fifty kilometres or runs for four hours with an average of thirty five kilometres per hours.

3. Methodology:

The Solar powered bicycle (fig.1) is a first of its kind vehicle with an overhead solar panel which can be used to recharge the Lithium-ion battery during commute as well as when the cycle is parked outside. Also, it can be charged by plugging in to the grid electricity at homes. The solar bicycle consists of 250W BLDC hub motor to drive the rear wheel when the rider wishes to use the electric assist , a 12V x 6 Ah lithium-ion battery, a 20W 12V solar panel on top, an MPPT to boost solar voltage to battery voltage and a basic metal frame and wheels. The solar panel needs to be welded to the bicycle frame at key locations to hold it firmly in place. The battery will need to be protected from the elements by placing it in GI sheet-metal box. The size of solar panel and the battery may vary during testing in order to increase or decrease range keeping cost in mind. Overall, we hope to achieve more than 30km of range from a single charge and yet be affordable to the average consumer especially in rural places to promote green energy vehicles.

Design Calculations:

Assumptions:

Wheel Diameter = 0.66m (26 inches)
Total weight = Cycle weight + Rider weight
= 19 + 65
=84 kg
Friction on bituminous surface = 0.012
Required speed = 25 kmph

1. Normal Reaction acting on each wheel:
   \[ N = \frac{84}{2} \times 9.81 = 412.02 \text{ N} \]

2. Frictional force on the tyre:
   \[ F = \mu \times N \]
   \[ = 0.012 \times 412.02 \]
   \[ = 4.94 \text{ N} \]

3. Torque:
   \[ T = F \times R \]
   \[ = 4.94 \times 0.33 \]
   \[ = 1.63 \text{ Nm} \]

4. Speed:
   \[ \omega = \frac{v}{r} \]
   \[ = \frac{25 \times 1000}{3600 + 0.33} \]
   \[ = 21.04 \text{ rad/sec} \]

5. Power:
   \[ P = T \times \omega \]
   \[ = 1.63 \times 21.04 \]
   \[ = 34 \text{ W} \]

This is the minimum motor power required for the bicycle to have motion taking into consideration wheel size, total weight, friction and the desired speed.

Total Power Required by the BLDC Motor:

\[ P_{Total} = P_w + P_{hill} + P_{roll} \]

Where,

\[ P_w = \frac{C_d \rho A}{2} \left( V_w + V_g \right)^2 V_g \]

**Power to overcome air drag**

Resistance by wind is strong at high speeds. [6]

\( C_d \) is the coefficient of air drag
\( \rho \) - Air density 6 kg/m\(^3\)
\( A \) - total area of the rider and the bicycle as seen from the front in m\(^2\)
\( v_w \) - Head wind speed in m/s
\( v_g \) - Ground speed in m/s

Coefficient of air drag is 1 for an upright cyclist.
Frontal area is assumed as 0.50 m\(^2\).

\[ P_{hill} = g m_{total} v_g G \]
Power during climbing
For uphill or downhill riding changes in potential energy is considered. [6]

Where

\( g \) - Gravitational acceleration is 9.81 m/s\(^2\),

\( m_{\text{tot}} \) - Total weight of the rider and the bicycle in kg,

\( v_g \) - Speed relative ground in m/s

\( G \) - Road grade (%)

\[ P_{\text{roll}} = gC_r m_{\text{tot}} v_g \]

Power to overcome rolling resistance
The rolling resistance is due to the tyres, bearings and other moving parts in the bicycle. Hence it depends on the design of the bicycle, also the speed and total weight of the rider and bicycle. [6]

Where

\( g \) - Gravitational acceleration in 9.81 m/s\(^2\),

\( C_r \) - Coefficient of rolling resistance,

\( m_{\text{tot}} \) - Total weight of the rider and the bicycle in kg

\( v_g \) - Speed relative ground in m/s

\[
W = \left[ \frac{(0.5*1.225*0.5)}{2} \right] \times (\frac{25000}{3600} + 0) \times (\frac{25000}{3600})
\]

\( = 51.28 \) W

\[
P_{\text{hill}} = 9.81 \times 0.02 \times (\frac{25000}{3600}) \times 84
\]

\( = 114.45 \) W

\[
P_{\text{roll}} = 9.81 \times 84 \times 0.012 \times (\frac{25000}{3600})
\]

\( = 68.67 \) W

Therefore,

\[
P_{\text{Total}} = 51.28 + 114.45 + 68.67
\]

\( = 234.4 \) Watt

Hence, a 250 Watt BLDC motor available in the market will be sufficient to achieve motion of the bicycle.

According to Wilson’s Bicycle Science three cases have been considered which corresponds to the following riding conditions: [4]

Case 1:
For speed greater than 11 km/hr major portion of the power is used to overcome the air drag

\[ \triangleright \text{Flat ground, high speed:} \]

\[ \triangleright \text{\( P_w \uparrow \uparrow \), \( P_{\text{hill}} \), \( = 0 \), \( P_w > P_{\text{roll}} \)} \]
Case 2:
For speed less than 11 km/hr and at level surfaces, major portion of the power is used to overcome the rolling resistance.
➢ Flat ground, low speed:
➢ $P_{\text{roll}} \uparrow\uparrow$, $P_{\text{hill}} = 0$, $P_{\text{roll}} > P_{\text{w}}$

Case 3:
Power required for overcoming air drag and rolling resistance is small when compared with the power required to overcome the slope on steep hill.
➢ Hilly ground, low speed:
➢ $P_{\text{hill}} \uparrow\uparrow$, $P_{\text{hill}} > P_{\text{w}}$, $P_{\text{hill}} > P_{\text{roll}}$

Charging time:

$$T = \frac{V \times Ah}{\text{Power}}$$

Where,
V = Voltage of the Battery
Ah = Battery rating (How much amperage a battery can provide in 1 hr)
Power = Wattage of the solar panel

$$T = \frac{(12.8 \times 6)}{20}$$

= 3.84 hr

Design:

![Isometric view of Solar powered bicycle](image)

Fig. 1 Isometric view of Solar powered bicycle

4. Conclusion:
Hope to increase the range of electric bicycles by 20% compared to commercially available e-bikes. Create a new useful sustainable product for society that will replace short distance travel by 2-wheeler ‘IC engine’ vehicles.
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