

Development of Eco-Friendly Hybrid E-Bicycle using Renewable Energy Sources

Sohel A. Kanoje¹, Vijay W. Kamble², Prajwal D. Amgaonkar³, Gaurav V. Hemane⁴,
Samiksha S. Lakhe⁵, Sonam K. Mandawkar⁶, Prof. Punam Mandhalkar⁷, Prof. Uttara Dudhpachare⁸

U.G. Student, Department of Electrical Engineering, Vidarbha Institute of Technology, Nagpur,

Maharashtra, India^{1,2,3,4, 5,6}

Assistant Professor, Department of Electrical Engineering, Vidarbha Institute of Technology, Nagpur,

Maharashtra, India^{7,8}

ABSTRACT: The increasing demand for sustainable and eco-friendly transportation systems has encouraged the development of renewable energy-based mobility solutions. This paper presents the design, development, and analysis of an eco-friendly hybrid e-bicycle using renewable energy sources. The Research Prototype model & system combines solar energy and battery-powered electric propulsion to reduce fuel consumption and environmental pollution. The hybrid e-bicycle consists of a solar panel, charge controller, battery bank, motor controller, BLDC motor, regenerative braking system, and bicycle wheel assembly. Design calculations for torque, speed, power requirement, battery specification, and charging time are carried out for a bicycle operating at a speed of 10 km/h. Experimental analysis of charging and discharging characteristics was also performed. The developed system demonstrated smooth propulsion, low operating cost, efficient battery utilization, and environmentally sustainable operation. The Research Prototype model & system hybrid e-bicycle can be effectively utilized for short-distance transportation in urban and rural areas...

KEYWORDS: Hybrid E-Bicycle, Renewable Energy, Solar Energy, BLDC Motor, Sustainable Transportation, Electric Vehicle, Green Energy, Regenerative Braking.

I. INTRODUCTION

The rapid increase in fuel prices, depletion of fossil fuel resources, and environmental pollution have created a strong demand for alternative transportation technologies. Renewable energy-based transportation systems are becoming increasingly important due to their low emissions and sustainable nature. Electric bicycles powered by solar energy provide an efficient and economical solution for short-distance transportation [1].

A hybrid e-bicycle combines manual pedaling with electric propulsion to reduce rider effort and energy consumption. The integration of solar energy with electric mobility enhances battery charging capability and improves operating range. Brushless DC (BLDC) motors are commonly used in electric bicycles because of their high efficiency, compact size, low maintenance, and reliable operation [5,6].

The objective of this work is to develop an eco-friendly hybrid e-bicycle using renewable energy sources and evaluate its performance through design calculations and experimental analysis. As we all know the fuel prices especially the petrol is rising steadily day by day. The pollution due to vehicles in metro cities & urban areas is increasing continuously. To overcome these problems, an effort is being made to search some other alternative sources of energy for the vehicles. Again, it is also not affordable to purchase vehicles (mopeds, scooters or motorcycles) for all the class of society. Keeping this in mind, a search for some way to cater these economically poor people as well as to provide a solution for the environmental pollution was in progress [2,3].

The solar assisted bicycle developed is driven by DC motor fitted in front or rear axle housing & operated by solar energy. The solar panels mounted on the carriage will charge the battery & which in turn drive the hub motor. When the bicycle is idle, the solar panel will charge the battery. This arrangement will replace the petrol engine, the gear box & the fuel tank in case of a two-wheeler or a chain sprocket, chain & gear shifting arrangement of a conventional bicycle being used by most common man. As a part of dissertation work, the solar assisted bicycle is fitted with a de

hub motor on front axle of a bicycle with power rating of 250W and with a travelling speed of around 25-30 km/h. It is provided with a pair of lead acid batteries of 35 Ah each, a photovoltaic solar panel with capacity of 20 watt, a voltage regulator of 24v 10 Amp, accelerator and motor controller of 24v 25Amp. There is also a provision for charging of the battery with 220-240V, AC wall output supply, in case of poor solar supply due to cloudy weather.

II. LITERATURE SURVEY

Rapid Several researchers have contributed to the development of solar-powered and hybrid electric bicycles for sustainable transportation applications. C. C. Chan [1] discussed the importance of electric and hybrid vehicle technologies in reducing environmental pollution and fossil fuel dependency. J. Larminie and J. Lowry [5] explained the working principles and design considerations of electric vehicle systems including batteries, motors, and power electronics.

Mousavi G. [3] presented the design and analysis of a solar-powered electric bicycle using renewable energy sources and highlighted the advantages of BLDC motors for lightweight transportation systems. Emadi et al. [4] investigated the role of power electronics and motor drives in electric and hybrid vehicles, emphasizing energy efficiency and motor control techniques. Das [7] designed and fabricated a solar-powered bicycle and concluded that renewable energy-based bicycles are effective alternatives for urban transportation. Gupta and Arora [10] analyzed the performance characteristics of solar-assisted electric bicycles and demonstrated improvement in travel range and energy efficiency using solar charging systems.

Previous studies mainly focused on solar charging systems, BLDC motor performance, and energy-efficient transportation. However, the integration of regenerative braking, dual charging capability, and smart hybrid features requires further investigation. The present work focuses on developing an eco-friendly hybrid e-bicycle with renewable energy integration, regenerative charging, and improved system efficiency.

III. METHODOLOGY

The reserach system is a Development of Eco-Friendly Hybrid E-Bicycle Using Renewable Energy Sources hybrid e-bicycle equipped with multiple advanced features. The bicycle uses a **BLDC motor powered by a rechargeable battery pack**. The rider can select between: Manual Pedal Mode, Electric Mode, Hybrid Mode.

In hybrid mode, both manual pedaling and electric motor assistance work together to reduce rider effort and improve efficiency, The bicycle also contains : LED headlight and tail light, Mobile charging unit, Digital speedometer, Battery status display, Horn system, Regenerative charging system, The system is designed to be lightweight, efficient, and economical.

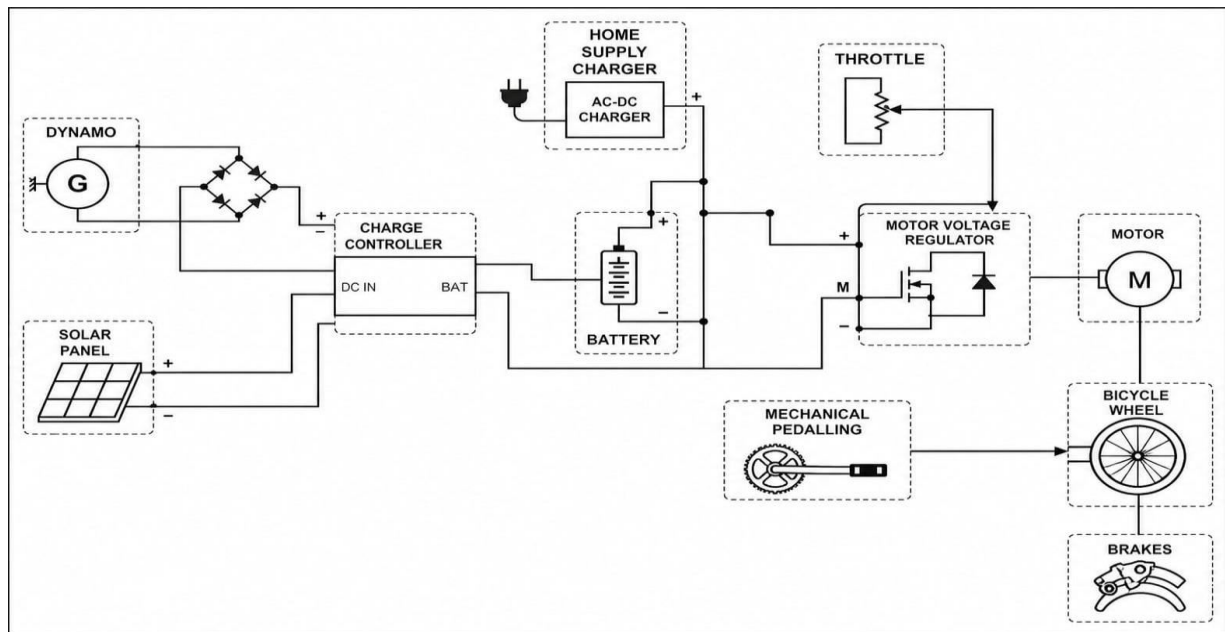


Fig.3.1. Circuit Diagram of Development of Eco-Friendly Hybrid E-Bicycle Using Renewable Energy Sources

The working of the solar-powered electric bicycle begins with the solar panel capturing sunlight and converting it into DC electrical energy. The generated electricity is regulated through the charge controller and stored in the battery. The stored energy is supplied to the motor controller, which controls the operation of the BLDC motor according to the throttle input. The motor then rotates the bicycle wheel, resulting in the forward movement of the bicycle

3.1 Solar Panel : The solar panel is the primary energy source of the system. It converts sunlight into electrical energy using the photovoltaic effect. The generated electrical power is in the form of direct current (DC), which is used for charging the battery and operating the motor system.

3.2 Charge Controller : The charge controller regulates the voltage and current generated from the solar panel before supplying it to the battery. It protects the battery from damage due to overcharging and deep discharge conditions.

3.3 Battery : The battery acts as an energy storage device in the system. It stores electrical energy generated by the solar panel and supplies power to the motor whenever required, especially during low sunlight conditions.

3.4 Motor Controller : The motor controller controls the operation, speed, and torque of the BLDC motor. It converts battery power into controlled electrical signals required for efficient motor performance.

3.5 BLDC Motor : The Brushless DC (BLDC) motor converts electrical energy into mechanical rotational energy. BLDC motors are preferred due to their high efficiency, low maintenance, and longer operational life.

3.6 Bicycle Wheel : The bicycle wheel receives rotational motion from the BLDC motor and converts it into forward movement of the bicycle.

The fabrication process involves fixing the different components to the frame of the bicycle. The motor is fixed to the front wheel shaft with proper alignment so that the weights are perfectly balanced. A battery casing in which 3 Li batteries of 12 V, 12Ah are fixed to frame and wiring are drawn from battery to motor so as to transmit power from battery to motor. Also wiring for speed control is also incorporated. Two solar panels are mounted on the roof top with newly fabricated roof top attached to the cycle. A solar charge controller is placed below the rear solar panel. Appropriate wiring is done to charge the battery through a jack for AC charging. This makes it possible to charge the battery either by solar power by electrical charging. The speed controller mounted in the handle cuts off the power

supply to the motor and stops it . The same brake stops the cycle with conventional friction brake. The braking system stops motor as well as cycle simultaneously.

The design involves the calculation of the power required to run a bicycle at a specified speed of 10 km/h and the development of a solar-powered system capable of supplying the required power. Since additional components such as the motor, batteries, and solar panel are mounted on the bicycle, a lightweight geared bicycle with suspension was selected. A 6-speed geared bicycle was used for the prototype model.

Design Calculations

✚ Normal Reaction

$$N_r = (100 \times 9.81) / 2 = 490.5 \text{ N}$$

✚ Friction Force

$$F = \mu N = 0.3 \times 490.5 = 147.15 \text{ N}$$

✚ Torque Required

$$T = F \times r = 147.15 \times 0.25 = 36.78 \text{ N-m}$$

✚ Speed Calculation

$$\omega = V/r = 11.11 \text{ rad/sec}$$

$$N = 106 \text{ RPM}$$

✚ Power Calculation

$$P = (2\pi NT)/60 = 408.2 \text{ W}$$

✚ Battery Specification : Three 12V, 12Ah batteries are connected in series to obtain 36V supply.

✚ Charging Time : Charging time = 3 hours.

Bicycle Data, Specifications and Performance Characteristics

Table: 3.1 Bicycle Data Specifications and Performance Characteristics.

Parameter	Specification
Rim Diameter	0.5 m
Wheel Radius	0.25 m
Bicycle Speed	10 km/h
Total Weight (Cycle + Rider)	100 kg
Coefficient of Friction	0.3

The solar assisted bicycle is driven by DC motor fitted in front axle housing & operated by solar energy. The solar panel mounted on the carriage is charge the battery & which in turn drive the hub motor. When the bicycle is idle during the day, the solar panel will charge the battery. The system will make bicycle operate more efficiently

IV. EXPERIMENTAL RESULTS & PERFORMANCE ANALYSIS

The developed hybrid e-bicycle successfully demonstrated dual-mode operation combining manual pedaling and electric propulsion.

Observations

- Smooth electric propulsion
- Reduced rider effort
- Effective regenerative charging
- Stable speed control
- Efficient battery utilization
- Reliable operation under varying load conditions

The system operated efficiently during testing and demonstrated practical applicability for short-distance transportation.

4.1. PERFORMANCE ANALYSIS

4.1.1. Battery Charging Characteristics

The charging of the battery is performed using solar energy. Experimental observations indicated that approximately 11 hours are required for complete charging under sunlight conditions. Due to variations in solar intensity, charging may require more than one day. The charging profile showed satisfactory performance with only minor deviations caused by weather conditions and changing solar radiation.

4.1.2. Battery Discharging Characteristics

The battery was connected to the motor during operation of the hybrid e-bicycle. The discharge process showed a nearly linear reduction in battery charge level over time. Experimental observations indicated approximately 3 hours of continuous operation under normal conditions.

4.1.3. Simultaneous Charging and Discharging

Simultaneous charging and discharging analysis showed improved operating range when solar assistance was active during operation. Experimental results indicated approximately 24% improvement in travel distance when the solar panel assisted battery charging during discharge.



Figure 4.1 (a) Final Model of Development of Eco-Friendly Hybrid E-Bicycle Using Renewable Energy Sources

V. CONCLUSIONS & FUTURE SCOPE

5.1. Conclusion

The Research Project titled “Development of Eco-Friendly Hybrid E-Bicycle Using Renewable Energy Sources” was successfully designed and implemented. The developed system combines solar energy and electric propulsion to provide an economical and environmentally sustainable transportation solution.

The integration of regenerative charging, efficient BLDC motor drive, and renewable energy sources improved overall system performance. The proposed hybrid e-bicycle reduces environmental pollution, minimizes fuel dependency, and supports sustainable mobility.

5.1.2. Advantages

- Eco-friendly transportation
- Reduced fuel consumption
- Low operating cost
- Dual power source operation
- Reduced rider effort
- Compact and lightweight design
- Rechargeable battery system
- Easy maintenance
- Regenerative braking capability

5.1.2. Applications

- Urban transportation
- College campuses
- Industrial areas
- Delivery services
- Tourism locations
- Fitness applications
- Smart city transportation

Hybrid e-bicycles have strong potential for future smart transportation and sustainable urban mobility applications.

5.2. Future Scope

Future improvements may include:

- IoT-based monitoring system
- GPS tracking, Bluetooth connectivity
- Smartphone application control AI-based energy management
- Advanced battery technologies, Fast charging systems
- Lightweight composite materials



Figure 4.2 Front View Final Model of Development of Eco-Friendly Hybrid E-Bicycle Using Renewable Energy Sources

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