Development and Fabrication of Hybrid Electric Bicycle

[1]Ms.Jayashree R, [2]Mr.Shylesh A, [3]Mr.Aromal EV, [4]Mr.Yuvaraj T ,[5]Mr.Rohan Joshua,
[6]Dr.N. Lakshmipathy, [7]Mr.Saravana Prasad
[1]UG student ,Dept of EEE, Dr.T.Thimmaiah Institute of Technology
[2,3,4,5]UG students, Dept of ME, Dr.T.Thimmaiah Institute of Technology
[6] Prof,HOD, Dept of EEE, Dr.T.Thimmaiah Institute of Technology
[7] Assistant Prof, Dept of ME, Dr.T.Thimmaiah Institute of Technology

Abstract

This project involves the design and development of a solar-assisted, geared E-bike that enhances efficiency, reduces rider effort, and promotes sustainable transportation. High-efficiency Photo Voltaic (PV) panels enable continuous solar charging, reducing reliance on plug-in charging and extending the bike's range. The geared transmission system improves torque control for smoother rides on varied terrains, while a regenerative braking system recaptures kinetic energy to recharge the battery. Testing demonstrated a 67% reduction in rider effort compared to traditional bicycles. The cost-effective, low-maintenance design provides an eco-friendly, practical mobility solution for urban and rural users, effectively meeting the project's objectives.
Keywords: Solar-assisted E-bike, Solar charging, Sustainable transportation, Renewable energy, Geared transmission system, Torque control, Regenerative braking system, Energy efficiency, Eco-friendly mobility.

I.Introduction

This project focuses on developing a geared hybrid solar-powered electric bicycle to address the limitations of traditional e-bikes, such as range and dependence on charging infrastructure. By integrating solar power with an electric drive system and a geared mechanism, the bicycle offers extended range, improved performance, and efficient energy management for smoother rides across varied terrains. The design incorporates a robust frame, optimized battery storage, and seamless integration of solar panels with mechanical and electrical systems. This innovation provides a cost-effective, eco-friendly transportation option for urban commuting and recreational use, empowering users to reduce their carbon footprint and operational costs while transitioning to sustainable mobility.

II. Objectives

- To develop a solar-assisted charging system and to enhance the E-Bicycle's performance through a geared system
- To improve energy efficiency with regenerative system of charging with cost-effective practical mobility solution

III. Components

1. Frame Design

The frame of a vehicle acts as its backbone, supporting and uniting various components while providing structural rigidity, handling, and safety. For an electric vehicle, a lightweight frame is advantageous and must be designed to accommodate the battery pack as shown in Fig-1.

Fig-1: Frame Design for Hybrid E-Bicycle

As bike frames experience complex stresses, engineers often start with proven designs and consider service load history during development. Key design considerations include the bike's dimensions and cyclist ergonomics, ensuring sufficient lateral and vertical clearance for safety and efficiency. Typical bicycle dimensions include a handlebar height of 0.75–1.10 m, a width of 0.61 m, and a length of 1.5–1.8 m. For this design, the adopted dimensions were 1200 x 200 x 860 mm.

2. Flywheel Design

Flywheels are designed to store and release kinetic energy. A Flywheel is disc shaped, and true to its weight on all sides and locations of the disk.

The flywheel is designed to provide a steadier flow of momentum. The size and weight of the flywheel will determine the amount of energy that can be produced from peddling the bike as shown in Fig-2.

Fig-2: Freewheel Design for Hybrid E-Bicycle

The mechanical advantages of using a flywheel is that its energy output is consistent and, depending on the size of the flywheel, it is able to store and release great amounts of energy even after the peddling has ceased. The kinetic energy stored in the flywheel is given as:

$KE = 1/2 * I * \omega$

where,

I=polar moment of inertia

ω= angular velocity of the flywheel

3. BLDC Hub Motor

The BLDC hub motor is a critical component of the hybrid electric bicycle, offering efficient propulsion and energy recovery with low maintenance. It operates without brushes, using electronic commutation for reduced friction and improved efficiency, and is integrated directly into the wheel hub for a compact design as shown in Fig-3. The motor converts battery power into mechanical energy for propulsion, while a torque

Fig-3: BLDC Hub Motor of 36V, 250W

sensor adjusts motor assistance based on rider effort, reducing fatigue and conserving energy. Additionally, its regenerative capability captures kinetic energy during braking or coasting, storing it in the battery to enhance efficiency. This dual functionality makes the BLDC hub motor essential for the bicycle's eco-friendly and sustainable performance.

4. Controller

The core function of an electric bike controller is to take all the inputs from all the electric components (throttle, speed sensor, display, battery, motor, etc.) and then determine what should be signaled in return to them (motor, battery, display) as shown in Fig-4.

Fig-4: BLDC Motor Controller for Hybrid E-Bicycle

Other multiple protection functions of the controller will be different from the controller's design

Following are some basic protection functions.

4.1. Over-voltage protection

The controller monitors the battery voltage and shut down the motor when the battery voltage is too high. This protects the battery from over-charge.

4.2. Low-voltage protection

The controller monitors the battery voltage and shut down the motor when the battery voltage is too low. This protects the battery from over-discharge.

4.3. Over-temperature protection

The controller monitors the temperature of the FET (Field Effect Transistor) and shut down the motor if they become too hot. This protects the FET power transistors.

4.4. Over-current protection

Reduce the current to the motor if too much current is being supplied. This protects both the motor and the FET power transistors.

5. Battery

The Lithium-ion battery, despite its lower energy-to-weight and energy-to-volume ratios, remains relevant due to its durability, low cost, and ability to deliver high surge currents, making it ideal for frequent use and applications requiring substantial power, such as electric bicycles.

Fig 5: Battery of 36V, 8.5 Ah

Its long cycle life, resilience to varying environmental conditions, and widespread availability enhance its practicality and affordability, providing a reliable and cost-effective power storage solution that supports the accessibility and adoption of electric bicycles across diverse consumer markets as shown in Fig-5.

6. Solar Panel

A solar panel is a device that converts sunlight into electricity. It is a crucial component in the field of renewable energy, enabling the capture of solar energy and transforming it into usable power. Solar panels are made up of numerous photovoltaic cells that harness the energy from the sun's rays as shown in Fig-6.

Fig-6: Solar panel of 36V, 9W

Solar panels operate on the photovoltaic effect, where photons from sunlight strike the semiconductor material (usually silicon) in the PV cells, creating an electric field across the layers. This electric field forces the flow of electrons, generating Direct Current (DC) electricity. The PV cells are sandwiched between layers of protective materials such as glass and polymer, providing durability and weather resistance. A standard solar panel consists of multiple interconnected PV cells, usually arranged in a grid pattern, to maximize energy production.

7. Torque Sensor

The Double Hall Pedal Assist System (DHPAS) with 12 magnets is an advanced sensor mechanism used in electric bicycles to detect the rider's pedaling motion and provide motor assistance accordingly. This system consists of two Hall effect sensors and a circular disc embedded with 12 evenly spaced magnets as shown in Fig-7.

The magnet disc is typically mounted on the crank arm or bottom bracket of the bicycle near the pedals, while the Hall sensors are fixed in proximity to this rotating disc. As the rider pedals, the magnets pass by the Hall sensors, generating a series of pulses. The system uses these pulses to determine the pedaling speed (cadence) and direction of rotation.

Fig-7:12 Magnet Torque Sensor

. The inclusion of 12 magnets ensures higher resolution and accuracy in detecting the pedaling motion compared to systems with fewer magnets. A greater number of magnets allows for quicker response times, as the system detects smaller increments of pedal movement.

8. Buck – Boost Converter

Buck-boost converter is a type of DC-DC converter that regulates voltage by either stepping it up (boost) or stepping it down (buck) depending on the input and output requirements as shown in Fig-8.In the hybrid electric bicycle, the buck-boost converter manages power flow between the solar panel, battery, and BLDC hub motor/generator, ensuring efficient voltage regulation. It operates in boost mode to step up low input voltage or in buck mode to step down high input voltage, protecting the system and optimizing charging.

Fig-8: Buck – Boost Converter with output (1-40V)

This adaptability is essential for handling fluctuating solar panel output and varying regenerative braking voltages. By maintaining consistent voltage for battery charging and power delivery, the buck-boost converter enhances energy efficiency, optimizes power transfer, and ensures reliable operation of the bicycle.

9. Rectifier

In regenerative mode, the rectifier converts the AC output from the BLDC hub motor, acting as a generator, into DC voltage to charge the battery as shown in Fig-9. A bridge rectifier, consisting of four diodes, ensures unidirectional current flow, converting the alternating AC waveform into pulsating DC.

A capacitor is added to smooth the DC output, reducing voltage ripples.

Fig 9: 3 phase Rectifier for Hybrid E-Bicycle

The buck-boost converter then adjusts the voltage to match the battery's charging requirements, ensuring efficient energy transfer and protecting the battery. This system enables recovered energy from braking or pedaling to be effectively utilized, enhancing the efficiency and sustainability of the hybrid electric bicycle.

IV. Working

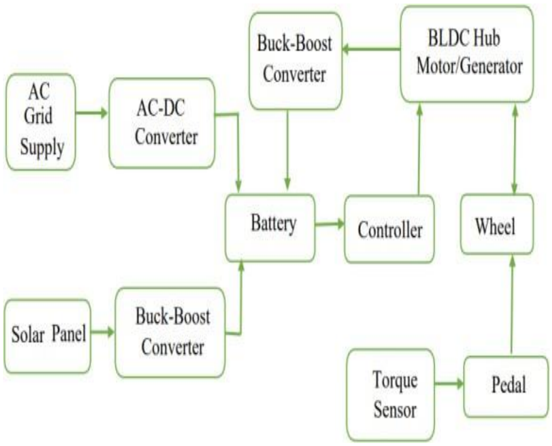

Fig-10: Block diagram

The block diagram for Hybrid E-Bicycle is shown in Fig 10 which consists of:

1. **AC Grid Supply**: This serves as an optional source of power, providing electricity directly from the grid to the system when needed.
2. **AC-DC Converter**: This component converts the AC power from the grid into DC power, which is suitable for charging the battery. It acts as an interface between the grid supply and the battery.
3. **Solar Panel**: The solar panel harnesses solar energy and converts it into electrical energy. It serves as the primary renewable energy source for the bicycle, helping to charge the battery.
4. **Buck-Boost Converter**: This converter regulates the voltage from the solar panel, ensuring that the output is consistent and suitable for charging the battery.
5. **Battery**: The battery stores the electrical energy converted from both the solar panel and the AC-DC converter. It provides power to the BLDC motor, ensuring continuous operation even when solar energy is not available.
6. **BLDC Hub Motor**: The BLDC (Brushless DC) hub motor, fitted to the front wheel, provides electric assistance for propulsion, reducing the physical effort required from the rider. It is powered by the stored energy in the battery.
7. **Wheel**: The wheel receives mechanical power from the BLDC motor, assisting the rider in forward movement and ensuring smoother riding experience.
8. **Pedal**: The pedal allows the rider to manually propel the bicycle. It is directly connected to the generator, enabling the conversion of mechanical energy into electrical energy during pedaling.
9. **Generator**: The generator, connected to the pedal, converts the mechanical energy generated during pedaling into electrical energy. This energy is then fed back into the battery for storage, helping to extend the battery life and providing additional power for the motor.
10. **Torque Sensor:** It measures the force applied on the pedal during manual pedaling and sends data to the controller, which uses this input to regulate motor assistance proportionally to the rider's effort.

V. Fabricated model

Fig-11: Final Assembly

VI. Results and discussion

1. For Mode 1- Motoring

The bicycle was driven with different load conditions with a constant speed of 10km/hr and the following results were obtained.

The different readings tabulated are shown in Table-1. The graph was plotted for voltage, current vs load as shown in Table 1.

Table-1: For Mode-1 At 10Km/hr

Sl No.	Load in Kg	Voltage in Volts	Current in Amps
01	60	4.96	9.81
02	66	5.2	9.90
03	76	5.4	10.2
04	82	5.8	10.03

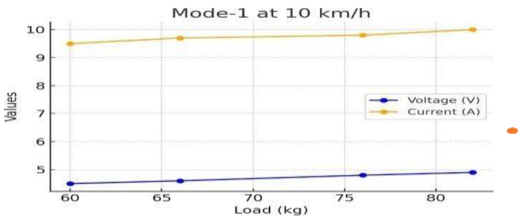

Fig-12: Graphical representation of Mode -1 at 10 km/hr

The current and voltage versus mechanical load (weight in kg) is plotted as shown in the graph. The graph reveals that as mechanical load increases the load current increases where in the voltage remains constant.

2. For Mode 2 - Motoring with Pedalling

Hybrid E-Bicycle was driven with different load conditions with a constant speed at 15 km/hr .

Table-2: For Mode-2 at 15km/hr

Sl No.	Load in Kg	Voltage in Volts	Current in Amps
01	62	4.0	9.8
02	69	3.5	9.9
03	71	3.3	10.2
04	74	2.9	10.03

The different readings tabulated are shown in table 2. The graph was plotted for voltage, current vs load as shown in Fig-13.

Fig-13: Graphical representation of Mode-2 at 15Km/hr

3. For Mode 3 - Regenerative Mode

Hybrid E-Bicycle was driven with different load conditions with a constant speed at 20 km/hr.

Table 3: For Mode-2 at 20km/hr

Sl No	Load in Kg	Voltage in Volts	Current in Amps
01	62	5	10.1
02	74	5	10.9
03	83	5	12.3

The graph was plotted for voltage v/s current as shown in Fig-14.

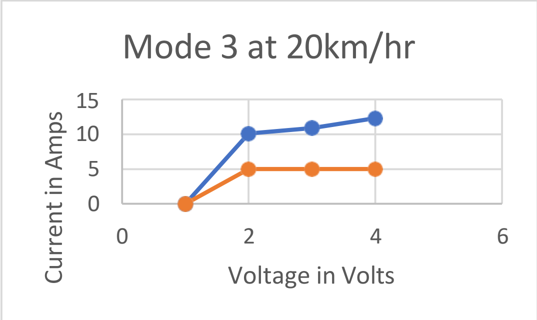

Fig-14 : Graphical representation of Mode-3 at 20Km/hr

The current and voltage versus mechanical load (weight in kg) is plotted as shown in the graph. The graph reveals that as mechanical load increases the load current increases where in the voltage remains constant.

VII. Advantages

1. Eco-Friendly Solution

The bicycle utilizes solar energy and regenerative braking, reducing reliance on non-renewable energy sources and minimizing environmental pollution.

2. Cost-Efficient Operation

By leveraging solar power and energy recovery, the operating cost is significantly reduced compared to conventional fuel-powered vehicles.

3. Extended Battery Life

The system uses solar charging, AC grid supply, and regenerative braking, ensuring multiple sources of power to maintain the battery's charge and extend its usage time.

4. Reduced Rider Fatigue
The double Hall pedal assist system provides proportional motor assistance based on pedalling effort, reducing physical strain on the rider, especially on inclines or long-distance rides.

5. Versatility in Power Sources
The ability to charge the battery through solar panels and AC grid supply makes the bicycle versatile and reliable in all weather conditions or locations.

VIII. Conclusion

The Hybrid Electric Bicycle powered by solar and AC supply represents an innovative step forward in sustainable transportation, combining the benefits of renewable energy and energy recovery systems. By integrating solar charging, AC grid charging, and regenerative braking, the bicycle not only offers an eco-friendly mode of transport but also optimizes energy usage to extend the range and improve overall efficiency. The BLDC hub motor, coupled with the pedal assist system, provides a seamless and enhanced riding experience, reducing physical strain while promoting an active lifestyle. The implementation of this project demonstrates how a hybrid system can effectively utilize solar power and regenerative energy to create an environmentally friendly and cost-effective solution for daily commuting and recreational riding. It also showcases the potential of integrating renewable energy solutions into personal transportation, contributing to reducing carbon emissions and promoting sustainable practices.

Though challenges such as high initial costs, weather dependency, and system complexity exist, the benefits of the project—such as energy efficiency, reduced carbon footprint, and long-term cost savings—make it a promising solution for future urban mobility. The hybrid electric bicycle not only aligns with the growing global shift towards sustainability but also offers practical applications in fields like tourism, delivery services, healthcare, and smart city initiatives.

In conclusion, the hybrid electric bicycle stands as a testament to the potential of green technologies in transforming the way we travel, highlighting the importance of renewable energy and energy recovery systems in shaping a cleaner, more sustainable future.

IX. Future Scope

1. Replace the normal changeover switch with an automatic system using MOSFETs or IGBTs.
2. Upgrade the solar panel wattage to improve charging efficiency.
3. Add a charge indicator to display charging activity during regenerative mode.
4. Install a gearing system on the second flywheel for enhanced performance.

References

[1] *Ian Vince McLoughlin et al., "Campus Mobility for the Future: The Electric Bicycle", "Journal of Transportation Technologies", Scientific Research, 2012, 2, 112*

[2] *Vivek Kumar et al., "Design & Implementation of Electric Assisted Bicycle with Self Recharging Mechanism".*

[3] *Adithya Kumar, Srirenga Venkatesh, Satheesh Kumar, Pragatheeshwarar"FABRICATION OF SELF-CHARGING ELECTRIC BIKE" International Journal of Pure and Applied Mathematics Volume 118No. 22 2018*

[4] *Shubham U. Tayde, Neha W. Makode, Umesh M. Laybar, and Prof. Bhushan S. Rakhonde "SELF POWER GENERATING ELECTRIC BICYCLE" International Research Journal of Engineering and Technology (IRJET) Volume: 04 Issue: 01 | Jan – 2017*

[5] *Ettore Pennestrì, Lorenzo Mariti, Pier Paolo Valentini, Victor Mucino (2011)*

[6] *Efficiency Evaluation of Gearboxes for Parellel Hybrid Vehicles: Theory and Applications(2011)*

[7] *C. J. L. Balsas, "Sustainable Transportation Planning on College Campuses," Transport Policy, Vol. 10, No. 1, 2003, pp. 35-49. doi:10.1016/S0967-070X(02)00028-8*

[8] *W. Toor, "Transportation & Sustainable Campus Communities: Issues, Examples, Solutions," Island Press, Washington DC, 2004.*

[9] *J. Rouwendal, "An Economic Analysis of Fuel Use per Kilometre by Private Cars," Journal of Transport Economics and Policy, Vol. 30, No. 1, 1996, pp. 3-14.*

[10] *J. Gardner, "Electrohydraulic/Air Bike," US Patent No. 4942936, 1990.*