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Solar Energy Assisted Electric Bicycle

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Abstract - The growing dependence on fossil-fuel-based transportation has led to increased greenhouse gas emissions, air pollution, and environmental degradation. To address these challenges, this work proposes a Solar-Assisted Electric Bicycle (SEB) that integrates photovoltaic energy with an electric propulsion system to provide a clean and affordable mobility solution. The system incorporates a lithium-ion battery, MPPT-based charge controller, DC–DC converter, and a compact solar panel for real-time energy harvesting. The prototype demonstrates reduced dependence on grid charging, lower operating costs, and improved travel range. Experimental results and analytical observations confirm that solar integration can significantly enhance endurance and reduce annual charging frequency, making the SEB a viable alternative for sustainable urban and semi-urban transportation.

Keywords - Solar-assisted bicycle, electric mobility, photovoltaic charging, sustainable transportation.

I. INTRODUCTION

Urban mobility has become a major contributor to energy consumption and greenhouse gas emissions due to the reliance on conventional fuel-powered vehicles[1][2]. Increasing traffic density, air pollution, and rising fuel costs have motivated the search for clean, efficient, and accessible transportation alternatives. Among the available options, electric bicycles (e-bikes) have emerged as practical, low-energy modes of transport for short to medium distances[4].The sustainability of e-bikes can be further enhanced by integrating renewable energy sources such as solar power[3]. Solar-assisted electric bicycles (SE-bikes) combine electric propulsion with photovoltaic (PV) generation to decrease grid dependency and reduce operational cost[5][6]. Compared to larger solar-powered vehicles, SE-bikes are structurally simpler, more economical, and easier to deploy.This study presents the development and evaluation of a Solar-Assisted Electric Bicycle prototype[7]. The work analyzes the design architecture, component integration, energy management strategy, and performance improvements achieved through solar charging[8]. The goal is to demonstrate the feasibility and benefits of SE-bikes as a sustainable mobility solution.

II .LITERATURE REVIEW

Rapid technological advancements in electric mobility and renewable energy have enabled several studies on solar-assisted vehicle systems. Early research focused on improving e-bike motor efficiency, lightweight structures, and battery performance. Recent studies emphasize integrating solar photovoltaic modules to extend range and reduce the frequency of grid charging.

Investigations conducted in regions with high solar irradiance, such as Hefei, have shown that solar-assisted e-bikes can extend daily riding range by more than 20 km under favorable weather. Annual simulations indicate a reduction in grid charging by up to 90% when solar panels are incorporated. These results highlight the potential of PV augmentation for sustainable mobility.

Several works highlight the significant role of Maximum Power Point Tracking (MPPT) controllers in improving energy harvesting efficiency despite fluctuations in sunlight. DC–DC converters and advanced battery management systems further stabilize the charging process. Additionally, advancements in lithium-ion battery technology—such as higher energy density and lower weight—have made them ideal for solar-assisted bicycles.

Environmental studies consistently show that SE-bikes significantly reduce carbon emissions and operating costs. The literature collectively demonstrates the feasibility, practicality,

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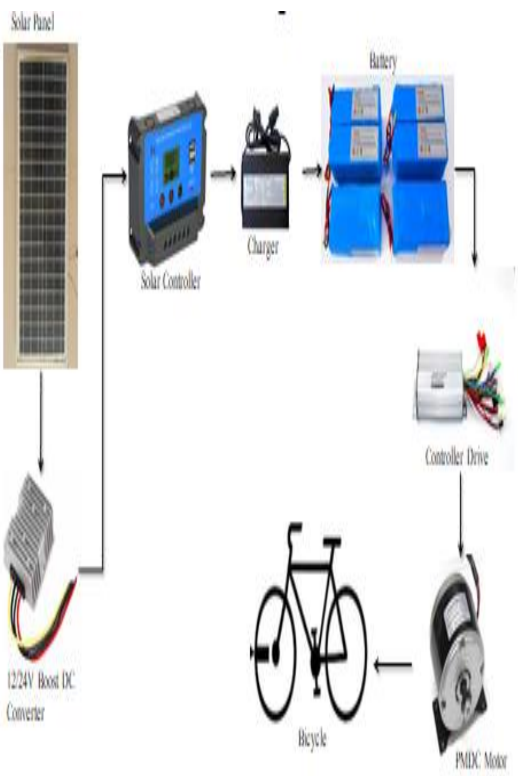
and environmental advantage of solar-assisted electric bicycles, forming the foundation for the present work

III. PROPOSED SYSTEM COMPONENTS AND ITS SPECIFICATION

The Solar assisted Electric Bicycle consists of the following key components:

- 24V, 250W PMDC Motor – Provides propulsion through a chain-drive mechanism.
- Lithium-Phosphate -ion Battery (24V, 10Ah) – Stores energy for motor operation.
- Solar Panel –50W ; Primary renewable energy source for charging.
- MPPT Charge Controller – Ensures optimal power extraction from the PV panel.
- Throttle and Controller Unit – Regulates speed and distributes power.
- Bicycle Frame – Supports added components with structural stability.



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A. System Specifications

1. Maximum Speed: 25–30 km/h
2. Motor: 24V, 250W PMDC chain-drive motor
3. Battery: 24V, 10Ah lithium-Phosphate-ion soft pack
4. Range per Charge: 25–30 km
5. Load Capacity: 160 kg
6. Charging Time: 3–4 hours
7. Display: Battery level indicator
8. Charger: 24V, 2A lithium-ion charger

3.1 Structural Integration The solar panel is mounted on the bicycle frame using lightweight supports that ensure stability without compromising aerodynamics. The panel placement maximizes sunlight exposure while maintaining proper balance. Quick-release mechanisms simplify maintenance and allow panel removal when necessary.

3.2 Charging-Discharging Mechanism The MPPT controller continuously tracks and adjusts the operating point of the solar panel to maximize output power. Under peak sunlight, the solar panel directly charges the battery. During low irradiance, the system automatically shifts to grid charging. The DC–DC converter minimizes conversion losses and stabilizes voltage, ensuring efficient energy transfer.

3.3 Prototype Fabrication A lightweight frame was selected to accommodate the battery, panel, and electrical circuitry without compromising ride comfort. Stability tests were performed to ensure that the additional components did not affect maneuverability. The prototype successfully met the design goals and demonstrated effective integration of solar charging with electric propulsion.

IV. PERFORMANCE ANALYSIS AND EXPERIMENTAL RESULTS

4.1 Experimental Setup Tests were conducted under typical urban sunlight conditions. Measurements included battery voltage, charging current, solar irradiance, and distance traveled. The prototype was evaluated for charging performance, endurance improvement, and reduction in grid dependency.

4.2 Solar Charging Performance Under clear sunlight, the system showed a steady rise in charging current. The battery could recover a substantial portion of its charge during daytime riding or parking. Partial shading reduced charging efficiency, highlighting the importance of optimal panel exposure.

4.3 Endurance and Range Improvement Field results indicate that solar assistance can extend riding range by up to 20 km per sunny day depending on terrain and rider weight. Daily commutes of 8–12 km can be completed with little or no grid charging during high-irradiance months.

4.4 Reduction in Grid Charging Annual estimates show that the SE-bike requires around 5 grid charges per year, compared to 60–70 charges for a conventional e-bike. This significantly reduces energy cost and improves battery lifespan.

4.5 Comparative Evaluation

Metric	SE-Bike	Conventional E-Bike
Additional Range	Up to 20 km/day	None
Annual Grid Charges	~5	~70
Operating Cost	Low	Moderate
Energy Source	Solar + Grid	Grid-only

Table 1. provides comparison between Solar assisted Electrical Bike and Conventional Bike

4.6 Block Diagram of Solar Assisted Electric bicycle

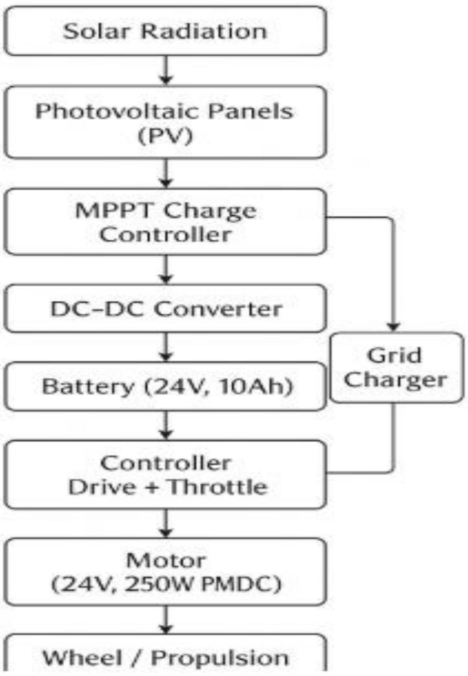
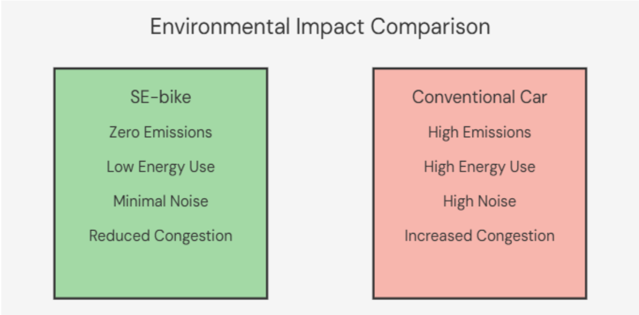


Fig 2: Energy flow diagram of the solar-assisted e-bike system showing the conversion of sunlight into stored electrical energy and its use in propulsion.

4.7Environmental Impact And Policy Implications

Solar-assisted electric bicycles offer substantial environmental advantages due to their low energy consumption and zero tailpipe emissions. An e-bike typically consumes 100–150 Wh per 100 km—significantly lower than motor vehicles. When powered through solar energy, indirect emissions from grid electricity are also minimized.

A single Solar Assisted electric bicycle can reduce up to 200–250 kg of CO_2 emissions annually, depending on usage and regional energy mix. Widespread adoption can help reduce urban congestion, noise pollution, and dependence on fossil fuels. SE-bikes also promote healthier commuting habits and align well with emerging clean-mobility policies and green transport incentives.



V. CONCLUSION

The Solar-Assisted Electric Bicycle developed in this study demonstrates a practical approach to integrating photovoltaic energy with electric mobility. The prototype shows significant improvements in range, energy efficiency, and reduction in grid charging frequency. With lightweight design, MPPT-based energy harvesting, and efficient power management, the SE-bike presents a viable option for sustainable transportation in urban and semi-urban environments. Continued improvements in solar panel efficiency, battery technology, and system optimization can further enhance performance and commercial adoption.

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