IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 6, June 2026

DOI: 10.17148/IARJSET.2026.13635

SELF CHARGING ELECTRIC BICYCLE USING SOLAR ENERGY

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Abstract: Nowadays and in future rising interest in sustainable and eco-friendly transportation has sparked the creation of self-charging electric bicycles that harness renewable energy. This project is all about designing and building a self-charging electric bike that features solar panels to recharge its battery while it's in use or parked, and even generates power through pedal rotation while riding. The system makes use of photovoltaic cells to turn sunlight into electrical energy, which is stored in a lithium-ion battery to drive the electric motor. This won't have to depends on external charging stations, allowing for a longer travel range and better energy efficiency. Our main goals include finding the best spots for solar panel placement to maximize energy capture, enhancing battery management, and ensuring the bicycle is both cost-effective and portable. The design aims to encourage green mobility by cutting down on fossil fuel use and greenhouse gas emissions, providing a sustainable option for urban transportation. It's an innovative and eco-friendly approach to getting around that reduces the need for outside charging sources. The growing demand for sustainable transport has spurred the development of energy-efficient and eco-friendly mobility solutions.

Keywords: The design reduces dependence on external charging sources and promotes eco-friendly transportation. It aims to improve energy efficiency, reduce pollution, and support sustainable urban mobility.

I.INTRODUCTION

Nowadays growing interest in eco-friendly and energy-efficient transportation has sparked the rise of electric bicycles. Yet, traditional e-bikes depends on external charging, which overcomes this problem, we're looking at a self-charging electric bicycle that harnesses solar energy. This innovative project incorporates a solar panel and a pedal generator to create electrical energy, which is then stored in a rechargeable battery. This stored energy powers a motor that drives the bicycle, cutting down on the need for outside power sources and encouraging the use of renewable energy for sustainable travel. Urban transportation is experiencing a significant transformation, driven by rising fuel prices, traffic jams, and environmental issues. Conventional vehicles that run on fossil fuels are major contributors to air pollution, noise, and greenhouse gas emissions. As cities grow and the demand for personal mobility increases, there's a pressing need for cleaner, smarter, and more efficient transportation options. Electric bicycles (e-bikes) have become a practical choice for short trips, offering convenience, less physical strain, and lower operating costs compared to traditional vehicles. Solar energy, being abundant, clean, and free, presents a fantastic opportunity to power small-scale mobility solutions. By adding solar panels to an electric bicycle, we can generate electrical energy directly from sunlight, significantly reducing our dependence on external charging facilities.

II.REVIEW OF LITERATURE

The growing worries about environmental pollution, the depletion of fossil fuels, and rising energy costs have pushed researchers to look for sustainable and energy-efficient transportation options. Electric bicycles have become a popular choice because they consume less energy, are affordable, and are easy to use. However, traditional electric bikes often rely heavily on external charging, which can be a hassle, especially in areas where electricity supply is unreliable. This situation has sparked a search for more self-sufficient energy solutions. In recent years, many studies have aimed at boosting the performance of electric bicycles by enhancing battery technology, motor efficiency, and energy management systems. Yet, these systems still depend on grid electricity, which indirectly contributes to environmental problems. To tackle this issue, researchers are increasingly exploring the integration of renewable energy, particularly

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solar power. By using photovoltaic panels to convert sunlight into electricity and store it in rechargeable batteries, we can reduce reliance on external power sources and improve sustainability. That said, the efficiency of solar-powered systems can be influenced by factors like weather, sunlight intensity, and the limited surface area of panels on bicycles, which can hinder continuous energy generation. To overcome these hurdles, hybrid systems that combine solar energy with pedal-driven generators have been suggested. These systems allow the mechanical energy generated while pedalling to be converted into electrical energy and stored for later use, enhancing overall efficiency and reliability. These hybrid solutions ensure that energy is available under different environmental conditions, making electric bicycles more practical. Despite these advancements, challenges such as high costs, system complexity, and inefficiencies in energy conversion still exist, which can limit their widespread adoption.

III.OBJECTIVE

To design and develop an eco-friendly and energy-efficient transportation system using renewable energy sources. The goal is to use solar panels to capture electrical energy, which will be stored in a lithium-ion battery to power an electric motor. Additionally, we're incorporating pedal-driven power generation to help cut down on the need for external charging. Another important objective is to promote sustainable and green transportation by minimizing fossil fuel use, reducing environmental pollution, and lowering greenhouse gas emissions. Ultimately, we want to offer a cost-effective, portable, and efficient mobility solution that's perfect for urban settings and short-distance travel.

IV.COMPONENTS

SOLAR PANEL: A solar panel works on the principle of the photovoltaic effect, which is all about turning sunlight directly into electrical energy. It consists of several photovoltaic (PV) cells, usually made from semiconductor materials like silicon. When sunlight hits these cells, the photons transfer their energy to the electrons in the semiconductor, making the electrons move and creating an electric current. This movement of electrons generates direct current (DC) electricity, which can be used right away or stored in a battery for later. The amount of electricity produced depends on various factors, including how intense the sunlight is, the angle of the panel, temperature, and whether there are any shadows.

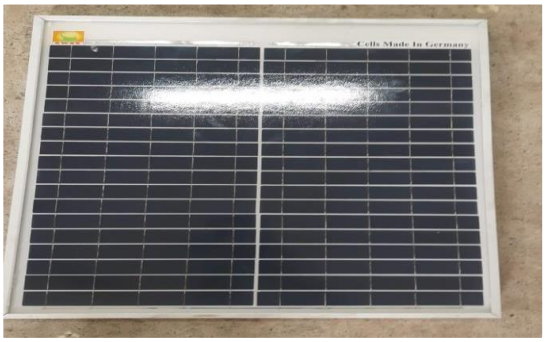

Fig.1 SOLAR PANEL

The specifications of a solar panel, like 12V and 10W, tell you about its electrical features and how much power it can generate. The “12V” rating indicates the nominal voltage of the panel, which is perfect for charging 12-volt batteries that are commonly found in smaller systems, such as electric bicycles. However, when the panel is in sunlight, its actual output voltage is usually higher, around 17–18 volts, to ensure effective battery charging. The “10W” rating shows the maximum power output of the panel under standard test conditions, meaning it can produce up to 10 watts of power when it gets optimal sunlight. Power is calculated by multiplying voltage and current ($P = V \times I$), so a 10W panel running at about 17 volts would generate roughly 0.5 to 0.6 amperes of current. In this project, the 12V, 10W solar panel serves as an additional energy source, helping to charge the battery and enhancing the overall efficiency and sustainability of the self-charging electric bicycle system.

ELECTRIC MOTOR (BLDC): The electric motor used in the proposed system is a Brushless Direct Current (BLDC) motor, which plays a crucial role in driving the electric bicycle by transforming electrical energy from the battery into mechanical motion.

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Fig.2 ELECTRIC MOTOR (BLDC)

Unlike traditional brushed motors, BLDC motors don't rely on physical brushes; they use electronic commutation instead. This design leads to greater efficiency, less friction, lower maintenance needs, and a longer lifespan. These motors are particularly well-suited for electric bicycles because of their compact size, smooth operation, and ability to provide consistent torque across a wide range of speeds.

For this project, we've chosen a 24V, 300 RPM, 250W BLDC motor to strike the perfect balance between performance and energy use. The 24V rating indicates the voltage supplied by the battery, ensuring it works seamlessly with standard low-voltage electric bicycle systems. With a speed of 300 revolutions per minute (RPM), this motor offers enough rotational speed for comfortable travel, making it ideal for urban commuting and short distances. The 250-watt power rating defines its output capability, which is more than enough to assist the rider while keeping energy efficiency in check and adhering to typical e-bike standards. This setup allows for smooth acceleration, dependable performance, and effective power use, making it a fantastic choice for a self-charging solar electric bicycle system.

LITHIUM-ION BATTERY: The lithium-ion battery is an essential part of the self-charging electric bicycle system. It acts as the main energy storage unit, providing electrical power to the motor and other electronic components. This battery works by storing energy in a chemical form and then releasing it as electrical energy when needed, ensuring a steady and reliable power supply during use. Lithium-ion batteries are popular in modern energy systems because they boast high energy density, are lightweight, have a low self-discharge rate, and offer a long cycle life compared to traditional batteries. Plus, they charge quickly and operate efficiently, making them perfect for electric vehicles and renewable energy systems.

Fig.3 LITHIUM-ION BATTERY

In this project, we're using a 12V, 7Ah lithium-ion battery, which strikes a great balance between capacity, weight, and performance. The 12V rating indicates the battery's nominal operating voltage, ensuring it works well with the motor and other electrical components in the system. The 7Ah (ampere-hour) capacity tells us how much charge the battery can hold, meaning it can provide 7 amperes of current for one hour under normal conditions. This capacity is just right for short to moderate travel distances while keeping things compact and portable. The battery can also be charged using both a solar panel and a dynamo generator, boosting the overall efficiency and sustainability of the system. So, the 12V, 7Ah lithium-ion battery is crucial for ensuring reliable energy storage and consistent performance in the electric bicycle.

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CHARGE CONTROLLER: The charge controller is a crucial electronic part of the self-charging electric bicycle system. It plays a key role in managing the flow of electrical energy between the power sources and the battery, ensuring everything runs safely and efficiently. This component regulates the voltage and current coming from the solar panel and dynamo generator, preventing issues like overcharging, deep discharging, and voltage spikes that could harm the battery and shorten its lifespan. By keeping the battery within its safe operating limits, the charge controller boosts the overall reliability and efficiency of the system. Plus, it optimizes energy use by making sure that the power generated is stored and distributed effectively based on the system's needs.

In this project, we're using a 24V, 250W charge controller to align with the electrical characteristics of the motor and energy system. The 24V rating shows that the controller is compatible with a 24-volt system, which is essential for proper voltage regulation during charging and power management. The 250W rating indicates the maximum power the controller can handle, allowing it to efficiently manage the energy produced by the solar panel and dynamo without risking overload. This ensures that the system performs steadily, even under different operating conditions. All in all, the charge controller is vital for protecting system components, enhancing energy efficiency, and ensuring the smooth operation of the self-charging electric bicycle.

BICYCLE FRAME: The bicycle frame is the primary structural component of the self-charging electric bicycle system, acting as the sturdy base that holds all the mechanical and electrical parts together in one seamless unit. It's crafted to deliver strength, rigidity, and stability while keeping things lightweight for smooth operation and easy handling. This frame is home to essential components like the electric motor, battery, solar panel mounts, controller unit, and wiring, ensuring everything stays aligned and secure while you're on the move.

Fig.4 BICYCLE FRAME

Choosing the right materials for the frame, usually steel or aluminium alloy, is vital for its durability, load-bearing ability, and resistance to the bumps and vibrations that come with riding. Beyond just being a structural support, the frame plays a key role in the bike's overall performance and safety by keeping balance and evenly distributing weight. A well-designed frame not only boosts rider comfort and maneuverability but also ensures stability in various conditions. Plus, it offers convenient mounting points for additional components, making it easy to integrate renewable energy systems without sacrificing the bike's mechanical strength. In short, the bicycle frame is a crucial part that not only holds everything together but also impacts the bike's efficiency, reliability, and long-lasting performance

DYNAMO GENERATOR: The dynamo generator is an important component in the self-charging electric bicycle system, responsible for converting mechanical energy into electrical energy. It works based on the principle of electromagnetic induction, where the motion created by pedaling or the movement of the wheels generates an electric current. In a typical bike setup, the dynamo is linked to the wheel via a roller mechanism or is built right into the hub, allowing it to spin along with the wheel. As it rotates, the dynamo generates either direct or alternating current, which can be used to charge the battery or power other components. This means that energy can be produced continuously while you're on the move, boosting the overall efficiency of the system. For this project, the dynamo generator serves as an extra power source that complements the solar panel in charging the battery. It adds reliability to the system by ensuring energy generation even when the sun isn't shining, like on cloudy days or during the night. While the power output from a dynamo generator is relatively modest compared to the main energy sources, its role in keeping the battery charged and extending the bike's operational range is quite significant. With its straightforward design, affordability, and ease of integration, it's a practical option for small-scale renewable energy projects. In short, the dynamo generator is essential for creating a hybrid energy system that champions sustainability and energy efficiency in self-charging electric bicycles.

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CONTROLLER UNIT: The controller unit is a crucial electronic component in the self-charging electric bicycle system. It's in charge of managing and coordinating all the electrical and electronic subsystems. Think of it as the brain of the operation, regulating how electrical energy flows from the battery to the electric motor based on what the user wants and the current riding conditions.

Fig.5 CONTROLLER UNIT

This controller picks up signals from various input devices like the throttle, brake sensors, and speed sensors, and it adjusts the motor's speed and torque to ensure a smooth and efficient ride. By employing electronic switching and control techniques, it allows for precise motor operation, boosts energy efficiency, and enhances overall riding comfort. But it doesn't stop there! The controller unit also plays a vital role in keeping the system safe and reliable by monitoring important parameters like voltage, current, and temperature. It acts as a safeguard against issues like over current, overheating, and short circuits, helping to protect critical components from damage. Plus, it enables communication between different parts of the system, including the display unit, which keeps the user informed with real-time data. With its compact design and ability to manage multiple functions, the controller unit is an essential part of modern electric bicycle systems. In short, it's key to optimizing performance, ensuring safety, and maintaining efficient energy management in self-charging electric bicycles.

WIRING & ELECTRICAL CONNECTIONS: The wiring and electrical connections are absolutely essential to the self-charging electric bicycle system. They play a key role in transmitting electrical power and control signals among various components. These connections tie together the solar panel, dynamo generator, charge controller, battery, controller unit, motor, sensors, and display unit, creating a cohesive system. When the wiring is done right, it ensures that the electrical energy generated from renewable sources is efficiently sent to the battery for storage and then delivered to the motor for propulsion. Typically, high-quality conductive materials like copper wires with proper insulation are used to reduce power losses and avoid short circuits or electrical issues during operation.

But it's not just about power transmission; the wiring system also enables communication between different electronic components by carrying control and feedback signals. For example, signal wires link sensors and input devices, such as throttle and brake controls, to the controller unit, allowing for real-time monitoring and precise motor performance control. Ensuring proper routing, insulation, and secure fastening of wires is crucial for safety, reliability, and durability, especially when faced with varying environmental and mechanical conditions. Additionally, using connectors, fuses, and protective elements boosts system safety by preventing over current and accidental damage. In short, a well-designed wiring and electrical connection system is vital for the smooth operation, energy efficiency, and long-term reliability of the self-charging electric bicycle.

V.WORKING PRINCIPLE

The working principle of the proposed self-charging electric bicycle is based on the integration of renewable energy generation, energy storage, and controlled power utilization to achieve efficient and sustainable operation. The system primarily utilizes solar energy as the main power source, where sunlight falling on the photovoltaic panel is converted into electrical energy through the photovoltaic effect. This generated electrical energy is then regulated by a charge controller, which ensures that the voltage and current are maintained within safe limits before supplying it to the battery. The battery stores this energy and acts as a reliable power source for the electric motor and other electrical components of the system.

From an operational perspective, the system is designed to deliver a balance between energy generation and consumption to maximize performance and reliability. The controller unit intelligently manages the distribution of

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power by supplying energy from the battery to the BLDC motor based on user input and real-time conditions, ensuring smooth acceleration and controlled speed. At the same time, continuous monitoring through sensors allows the system to maintain optimal performance while preventing issues such as overloading or excessive energy loss. The hybrid energy approach not only enhances battery life but also reduces dependency on external charging, making the system suitable for use in remote and urban areas alike. Overall, the coordinated functioning of energy generation, storage, and control mechanisms enables the bicycle to operate efficiently as a self-sustaining and environmentally friendly transportation system.

In addition to solar energy, the system incorporates a dynamo generator that converts mechanical energy produced during pedalling into electrical energy using electromagnetic induction. This hybrid setup guarantees a steady flow of energy, even when the sun isn't shining, which boosts the system's reliability. The battery stores this electrical energy and sends it to the Brushless Direct Current (BLDC) motor via a controller unit. This unit smartly adjusts the motor's speed and torque based on user inputs like throttle control and the riding conditions. Meanwhile, sensors keep a close eye on important system metrics such as voltage, current, and speed, feeding this information back to the controller to ensure everything runs smoothly and safely. By combining solar and mechanical energy with smart energy management and control systems, this bicycle becomes a self-charging, eco-friendly, and energy-efficient way to get around.

VI.BLOCK DIAGRAM

Fig.6 PROTOTYPE MODEL

VII.ANALYSIS

The self-charging electric bicycle is a fantastic and eco-friendly option for our future transportation needs. By integrating solar power and pedal energy generation, the system improves energy efficiency and supports green mobility. This project demonstrates the practical application of renewable energy technology in everyday transportation while reducing pollution and energy consumption.

Technical Analysis

The self-charging electric bicycle is a clever blend of solar energy and pedal power, creating a unique way to get around. Its design features solar panels, a pedal-driven generator, a lithium-ion battery, a charge controller, and a DC motor. The solar panels harness sunlight through photovoltaic cells, turning it into electrical energy that gets stored in the battery for later use. When you pedal, the mechanism spins a generator that adds even more electrical energy, boosting the charging efficiency. This stored energy then powers the electric motor, making it easier for you to ride. Plus, a battery management system keeps everything in check, ensuring safe and efficient energy use. The whole setup is crafted to make the most of renewable energy while being portable, reliable, and low on maintenance.

Performance Analysis

The performance of the self-charging electric bicycle depends on the efficiency of the solar panel, battery capacity, motor performance, and pedal power generation. By solar charging system, the bicycle can continuously generate energy whenever it's exposed to sunlight. while the pedal generator supplies supplementary power during riding. This dual charging mechanism improves battery backup and extends the travel range compared to conventional electric bicycles. The bicycle operates with minimal environmental impact because it does not depend completely on external

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electricity or fossil fuels. The lithium-ion battery provides stable power output, fast charging capability, and longer service life. The system demonstrates improved energy efficiency, reduced operational cost, and eco-friendly performance, making it suitable for short-distance urban transportation and sustainable mobility applications.

Challenges and Opportunities

The self-charging electric bicycle using solar energy faces several challenges as well as opportunities in the field of sustainable transportation. One significant challenges is the inconsistent availability of solar energy, especially during cloudy days or at night, which can really reduces charging efficiency. in addition, there's the issue of limited space for solar panels, which directly impacts how much power can be generated. On top of that, combining solar panels, batteries, motors, and pedal generators adds weight and complexity to the bicycle. The charging speed from solar and pedal power is relatively slow, and the initial cost of components such as lithium-ion batteries and photovoltaic panels is comparatively high. Proper battery management and maintenance are also necessary to ensure safe and efficient operation.

Despite these challenges, the project offers significant opportunities for future transportation systems. It promotes the use of renewable energy and reduces dependence on fossil fuels and external electricity sources. The bicycle provides an eco-friendly and cost-effective mobility solution with low pollution and reduced greenhouse gas emissions. They're perfect for short trips in urban areas and can really boost green mobility efforts. The project also creates opportunities for further technological advancements such as smart battery management systems, loT-based monitoring, regenerative braking, and high-efficiency solar panels. Overall, the self-charging electric bicycle represents an innovative and sustainable approach toward clean and energy-efficient transportation.

VIII.FUTURE STUDIES

The self-charging electric bicycle has significant scope for future research and development in the field of sustainable transportation and renewable energy systems. Future studies can focus on improving the efficiency of solar panels by using advanced photovoltaic materials and flexible lightweight solar cells that can capture more sunlight with less space. Additionally, enhancing the battery system with high-capacity, fast-charging batteries could extend travel range and cut down on charging time. Researchers can integrate regenerative braking systems to recover energy during braking and further improve overall energy efficiency.

In the future, we can expect to see smart technologies like IoT-based monitoring systems, GPS tracking, mobile app controls, and real-time battery management being integrated to make bicycles smarter and more user-friendly. Artificial intelligence and energy optimization algorithms may also be used to manage power distribution efficiently between solar charging, pedal generation, and motor usage. Additionally, lightweight materials and improved motor designs can help cut down the total weight of the bicycle and improve performance.

Future studies can also explore large-scale implementation of self-charging electric bicycles in smart cities, on college campuses, and within public transportation systems to promote green mobility and tackle environmental pollution. With continuous advancements in renewable energy and electric vehicle technologies, the project has strong potential to become a practical, economical, and sustainable transportation solution for the future.

The idea behind a self-charging electric bicycle powered by solar energy, as explored in this project, shows great potential for creating sustainable and energy-efficient transportation. The integration of solar energy and mechanical energy generation has reduced dependence on conventional charging methods. However, there is significant scope for further development and enhancement of this system for wider applications in transportation and renewable energy sectors.

Enhanced Solar Panel Efficiency:

We can boost the system's performance by utilizing high-efficiency photovoltaic panels that offer better energy conversion rates, which would speed up charging and increase overall energy generation.

Cutting-Edge Battery Technology:

Future upgrades could involve using high-capacity lithium-ion or solid-state batteries that charge faster and last longer, ultimately improving the bike's range and reliability.

Smart Control System Integration:

We could take the system to the next level by adding smart control units and IoT-based monitoring systems. This would allow for real-time tracking, performance optimization, and better energy management.

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Lightweight and Aerodynamic Design:
Further research could focus on making components lighter and enhancing the bike's aerodynamic design to improve speed, efficiency, and comfort for the rider.

Commercial and Smart City Applications:
This system could be scaled up for broader uses, such as in public transport, delivery services, and shared mobility solutions, playing a key role in the development of smart cities and promoting green transportation initiatives.

IX.CONCLUSION

The current project focuses on a self-charging electric bicycle powered by solar energy, and it has been successfully designed and analyzed. This innovative approach paves the way for sustainable and energy-efficient transportation. By combining a photovoltaic panel, a dynamo generator, a battery storage system, and an electric motor, we've created a hybrid energy mechanism that allows for continuous energy generation and use. This system significantly cuts down on the reliance on traditional charging methods by harnessing renewable solar energy and the mechanical energy produced while pedalling.

When we evaluated the performance of the system, we found that the electric bicycle can achieve satisfactory speed, range, and operational efficiency in real-world conditions. The use of a BLDC motor ensures a smooth and reliable ride, while the battery consistently supplies energy with good charging and discharging capabilities. Additionally, the inclusion of a charge controller and a control unit boosts the system's safety and efficiency by managing power flow and safeguarding components from electrical issues.

While there are some limitations, such as reliance on sunlight and restricted power generation, the overall performance of the system proves to be dependable for short-distance travel and daily commuting. In summary, this proposed system presents an eco-friendly, cost-effective, and practical solution for today's transportation needs. It plays a role in reducing environmental pollution and encourages the use of renewable energy sources in mobility. This project also showcases the potential for further enhancements and scalability, marking a promising step toward developing sustainable and green transportation systems for the future.

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