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## Fabrication of Solar Powered E-Bicycle

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### Abstract:

The project titled “Fabrication of Solar Powered E-Bicycle” aims to develop an eco-friendly, efficient, and cost-effective transportation system by integrating solar energy with electric propulsion and manual pedaling. The proposed system utilizes a combination of a solar panel, rechargeable battery, electric motor, and control unit to operate the bicycle in multiple modes such as manual, electric, and hybrid. The solar panel converts sunlight into electrical energy, which is stored in a battery through a charge controller. This stored energy is used to power the motor and conventional electricity. The system also incorporates pedal assist and regenerative braking features to improve energy efficiency and extend battery life. The design focuses on improving performance, safety, and user experience, while promoting sustainable transportation. The fabricated prototype is equipped with a rechargeable battery system, electric motor, and advanced control systems, enabling efficient energy management and smooth operation. The fabricated prototype demonstrates improved performance, reduced carbon emissions, and enhanced user convenience. This project promotes sustainable transportation and provides a practical solution for short-distance travel, especially in areas with limited charging infrastructure. Overall, the solar powered e-bicycle represents an innovative step towards green mobility and energy conservation.

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### Introduction:

With increasing environmental pollution and depletion of fossil fuels, there is a growing need for sustainable transportation solutions. Solar powered electric bicycles (e-bikes) combine renewable energy with electric mobility, offering an efficient and eco-friendly alternative. The world is undergoing a significant transformation, driven by the urgent need for sustainable transportation solutions. The alarming rates of environmental degradation, coupled with the depletion of non-renewable energy sources, have necessitated a paradigm shift in the way we travel. Solar bicycles (e-bikes) have emerged as a promising solution, offering a unique blend of traditional cycling and electric power. By combining human pedalling with electric motors, e-bikes provide a cleaner, healthier, and more efficient alternative to conventional transportation methods. A solar bicycle is an advanced type of electric bicycle that uses solar panels to charge its battery using sunlight. It works on renewable energy and reduces dependence on conventional electricity. Solar bicycles are mainly developed as innovative and eco-friendly transportation solutions. This project aims to push the boundaries of e-bike technology, designing and building a multi-driven e-bike that integrates human pedalling, electric motors, and solar energy. By harnessing the power of these three energy sources, our e-bike will provide a sustainable, efficient, and environmentally friendly transportation solution for the future.

## BACKGROUND :

The escalating concerns over environmental degradation and the depletion of non-renewable energy sources have intensified the global pursuit of sustainable transportation alternatives. Electrical & Solar bicycles (e-bikes) have gained prominence as eco-friendly solutions, merging traditional cycling with electric propulsion to offer an efficient and versatile mode of transport. E-bikes are equipped with rechargeable batteries that power electric motors, providing riders with assistance that reduces physical exertion and enables longer commutes. This fusion of human and electric power not only diminishes dependence on fossil fuels but also contributes to decreased urban congestion and promotes healthier lifestyles. The concept of electric bicycles has been around since the late 19th century, with the first patent for an electric bicycle granted to Ogden Bolton Jr. in 1895. However, it wasn't until the 1990s that e-bikes began to gain popularity as a sustainable and environmentally friendly transportation solution. Developed as a renewable energy transportation solution. Popular in engineering projects and eco-friendly innovations. Used in rural areas where electricity charging stations are limited.

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## PROBLEM STATEMENT :

While e-bikes offer numerous advantages, their widespread adoption faces challenges related to performance optimization and user adaptability. Conventional e-bike designs often rely on a single power source, limiting their efficiency across diverse terrains and rider preferences. Furthermore, the seamless integration of multiple power inputs—such as human pedalling, electric motors, and alternative energy sources like solar power—remains underexplored. The solar panels produce limited electrical output, particularly under low sunlight conditions such as cloudy or rainy weather. Integration of solar panels into the bicycle frame increases overall size and may affect aerodynamics, stability, and rider balance. The inclusion of photovoltaic panels and charge controllers significantly increases the initial manufacturing and installation cost. Solar panels are continuously exposed to environmental factors such as dust, moisture, and mechanical impacts, which may reduce performance and lifespan. An efficient and reliable battery system is required to effectively store and manage the energy generated from solar panels. Additionally, a significant concern for e-bike users is the limited range and dependence on battery charging. When batteries run out, and charging stations are not nearby, riders are left stranded. This limitation can be overcome with a multi-driven approach, which provides a reliable and efficient solution for extended rides. Addressing these challenges is crucial to enhancing the functionality, appeal, and environmental benefits of e-bikes.

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## OBJECTIVES :

- The primary objectives of this project are:
- To utilize solar energy for transportation: The main objective is to use sunlight as a renewable energy source to power a bicycle.
- To reduce dependence on fossil fuels: The project aims to minimize the use of petrol and diesel for short-distance travel.
- To develop an eco-friendly transportation system: Solar bicycles help reduce air pollution and support a clean environment.
- To design a simple and low-cost vehicle: The objective is to create an affordable and energy-efficient transport system.
- To promote sustainable energy technologies: The project encourages the use of renewable energy in daily life.
- To demonstrate the working of solar energy systems: It helps students understand how solar panels, batteries, and motors work together.

- To improve energy efficiency in mobility: The project focuses on maximizing the use of solar power for better performance.
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## SCOPE OF THE STUDY :

- The focus on developing an eco-friendly transportation system that uses renewable solar energy. This project has wide applications in sustainable mobility and energy conservation.
  - The project demonstrates how solar energy can be used to generate electricity for transportation using solar panels and batteries.
  - It helps reduce air pollution and carbon emissions compared to fuel-based vehicles.
  - The project opens opportunities to improve solar panel efficiency, battery storage systems, and lightweight designs.
  - Solar powered bicycles can provide an economical travel option for students and daily commuters.
  - With technological advancements, solar bicycles can become an important part of sustainable and green transportation systems.
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## Literature Review

### Historical Development:

- The Photovoltaic Revolution (1980s–2000s)
- The "Solar" component emerged as photovoltaic (PV) technology moved from laboratory curiosity to practical application.
- The 1980s: Experimental solar cycles appeared in competitions like the Tour de Sol. These early prototypes often used large, overhead solar "roofs" to compensate for the low efficiency (roughly 10%) of early silicon cells.
- 1990s: The shift from Nickel-Cadmium (NiCd) to Lithium-Ion (Li-ion) batteries in the late 90s was a turning point. Li-ion batteries could store the intermittent energy from solar panels much more efficiently and at a fraction of the weight.
- 2000: Designer Miroslav Miljevic developed early concepts for solar-powered batteries specifically for commuters, aiming to allow bikes to charge while parked outside during the workday.

### Market Trends and Adoption:

- The evolution of e-bikes reflects changing societal needs and technological innovations.
  - Global e-bike sales have surged, driven by factors like increasing urbanization and environmental awareness.
  - Infrastructure Gaps: A lack of dedicated, secure "solar-parking" lanes where bikes can charge safely in the sun without risk of theft or vandalism.
  - Different regions exhibit varying adoption rates, influenced by infrastructure and cultural factors.
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## METHODOLOGY :

The development of a multi-drive electric & Solar Powered bicycle necessitates a comprehensive approach that integrates mechanical, electrical, and control systems engineering. This chapter outlines the design methodology, implementation steps, and the tools and technologies employed in the project.

### Design Approach

#### Multi-Drive System Conceptualization

The primary objective is to engineer a propulsion system that seamlessly combines human pedalling with electric motor assistance. This dual-input mechanism aims to enhance energy efficiency and optimize the bicycle's range, providing a balanced and responsive riding experience.

### Modular Design

Adopting modular architecture facilitates straightforward integration of components and allows for future scalability. Distinct modules will be developed for the electric propulsion system and the control unit, ensuring ease of maintenance and potential upgrades.

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## IMPLEMENTATION STEPS

### Component Selection and Procurement

Key components such as the electric hub motor, battery pack, and control systems will be selected based on criteria including performance metrics, energy efficiency, and cost-effectiveness.

### Mechanical Fabrication

The bicycle frame will be constructed using high-strength steel alloys, known for their durability and favorable strength-to-weight ratios. The frame will be engineered to accommodate the multi-drive system components seamlessly.

### Electrical System Integration

Integration of the motor, battery, and control units will be meticulously executed to ensure cohesive operation. Wiring harnesses will be organized to minimize clutter and potential interference, adhering to best practices in electrical engineering.

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## Tools and Technologies

### Used

#### Design Tools

- **Computer-Aided Design (CAD) Software:** Utilized for precise modeling of mechanical components and assemblies.
- **Circuit Design and Simulation Software:** Employed to develop and validate electrical schematics and PCB layouts.
- **Embedded Systems Development Platforms:** Used for programming and testing microcontroller-based control systems.

## Fabrication Tools

- **Welding Equipment:** For assembling the steel alloy frame and ensuring structural integrity.
  - **3D Printers:** To create prototypes of custom components and enclosures.
  - **CNC Machines:** For precision machining of parts and brackets.
  - **Soldering Stations and Wire Crimpers:** Essential for assembling and securing electrical connections.
- Testing and Measurement Tools

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## System Design and Components

- The development of the Solar Powered E-Bicycle encompasses several critical components, each meticulously designed and selected to ensure optimal performance, durability, and user comfort. This chapter delves into the specifics of the frame design, motor and battery system, control system, Solar Panel and sensor integration.

Frame design is an important part of a solar panel because it supports and holds the solar panel securely while the bicycle is moving. The frame must be strong, lightweight, and stable so that it does not affect the balance of the bicycle.

### Frame Specifications:

Material: Aluminum Alloy Weight: Approximately 4.5 kg Size: 21 inches

Type: Hardtail mountain bike frame Tire Size: 90cm\*55cm

Aluminum alloys are renowned for their high strength-to-weight ratios, making them ideal for bicycle frames. Specifically, alloys such as 6061 are commonly used due to their excellent weldability, corrosion resistance, and mechanical properties. The 6061 alloy, for instance, offers a tensile strength ensuring a robust yet lightweight frame.

### Motor and Battery System

The propulsion system of the electric bicycle is centered around a brushless DC (BLDC) motor hub paired with a lithium-ion battery pack. This combination is selected for its efficiency, reliability, and performance

### Motor Specifications:

Type: Brushless DC (BLDC)

motor hub Voltage: 36V Power Output: 250 Watts Torque: 40

Newton-meters (Nm) Efficiency:

Approximately 85% Battery Specifications:

Type: Lithium-ion

Capacity: 10 Ampere-hours (Ah) Voltage: 36 Volts (V)

Energy Density: Approximately 120 Watt-hours per kilogram (Wh/kg)

## WORKING PRINCIPLE :

The Solar powered E-Bicycle is engineered to respond to varied riding conditions and user needs by operating in three primary modes: **Manual**, **Electric**, **Solar Panel** and **Hybrid**. This multi-modal design leverages both traditional mechanics and advanced electronics to optimize performance, enhance energy efficiency, and improve safety.

### Manual Mode

In Manual Mode, the bicycle operates solely on human power. The mechanical drivetrain—comprising a calibrated chain and gear system—translates the rider's pedaling effort into forward motion. This mode is particularly beneficial for riders who prefer a traditional cycling experience and wish to preserve battery life for extended journeys. Additionally, Manual Mode serves as a fail-safe option in case of battery or electronic system issues. A well-integrated display unit can provide real-time information such as speed, distance traveled, and cadence, further enriching the riding experience.

### Electric Mode

In Electric Mode, the bicycle is powered entirely by its electric motor, which draws energy from a rechargeable battery pack. This mode is ideal for covering longer distances with minimal physical effort. Key features include:

- **Battery Management System (BMS):** The rechargeable battery pack is coupled with a sophisticated BMS that regulates charging/discharging cycles and ensures safe power delivery to the motor.
- **Electronic Speed Controller (ESC):** The motor's performance is fine-tuned by the ESC, which adjusts motor output based on factors such as speed, terrain, and load.
- **Optimized Energy Delivery:** Through continuous sensor feedback, the control system maintains optimal power distribution, ensuring smooth acceleration and deceleration during rides.
- **Additional Features:** Some implementations may include regenerative braking, wherein kinetic energy is recovered during deceleration and fed back to the battery.

This integration of electric propulsion minimizes rider fatigue while offering a reliable and efficient mode of transit for commuting or recreational riding.

### Solar Powered Mode

The Solar Powered E-Bicycle is based on converting sunlight into electrical energy and using that energy to run an electric motor that moves the bicycle.

- **Solar Energy Collection:** A solar panel is mounted on the bicycle (usually above the rear wheel or as a small canopy). The panel contains photovoltaic (PV) cells. These PV cells convert sunlight into electrical energy (DC power).
- **Power Supply to Motor:** When the rider switches on the system, the battery supplies power to the electric motor. The motor is usually attached to the rear wheel hub or chain drive.
- **Continuous Charging:** While the bicycle is parked or moving in sunlight, the solar panel continues to charge the battery. This helps increase the travel distance and reduce dependence on grid electricity.
- **Battery Charging:** The electricity produced by the solar panel is sent to a battery through a charge controller. The charge controller regulates the voltage and protects the battery from overcharging. The battery stores the electrical energy for later use.

## Results and Discussion

The Solar Powered E-Bicycle was successfully designed and tested to operate using solar energy. The solar panel generated electrical energy from sunlight and charged the battery through the charge controller. The stored energy in the battery powered the

DC motor, which helped the bicycle move smoothly. During testing, the bicycle was able to run efficiently for short distances with the support of solar charging and pedal assistance. The system showed that solar energy can be effectively used as an alternative power source for small transportation systems. Measurements were conducted both in controlled environments and in real-world conditions to guarantee reliable results.

- **Speed Achieved in Different Modes:** The evaluation revealed distinct performance characteristics across the three operational modes.
  - **Manual Mode:** Relying solely on rider input, the bicycle maintained an average speed of **12–18 km/h**, which varied with rider strength and terrain gradient.
  - **Solar Mode:** Depends on the solar panel output, battery capacity, and motor power used in the bicycle. The average speed achieved in solar mode is about **15–20 km/h** under normal sunlight conditions.
  - **Electric Mode:** The motor-driven propulsion enabled speeds ranging from **20–25 km/h** under typical urban conditions, with the electronic speed controller ensuring smooth acceleration and deceleration.
  - **Hybrid Mode:** This mode provided a combined benefit, with electric assistance augmenting the rider's effort. As a result, users experienced a stable and often enhanced speed profile that effectively balanced manual and motor inputs, especially during partial climbs or variable terrain.
- **Battery Life and Charging Time:** The battery performance metrics were a critical focus of the evaluation.
  - The rechargeable lithium-ion battery pack was able to deliver an operational range of up to **45 km** on a full charge in Electric Mode, under average load conditions.
  - Charging protocols indicated that a complete recharge typically required between **3–4 hours**, making it viable for daily commuting needs.
  - In Hybrid Mode, the effective battery drain was further minimized due to the shared load with the cyclist's pedaling effort, thereby enhancing overall energy sustainability.

## Challenges and Limitations

### Technical Challenges

Developing a high-performance, Solar Powered E-Bicycle involves overcoming several technical hurdles that impact both immediate performance and long-term sustainability:

**High Initial Cost of Components:** The integration of advanced technologies—such as high-capacity lithium-ion batteries, precision sensors (torque, speed, and cadence sensors), and intelligent control units—drives up the initial cost of the bicycle. High-quality components are essential for ensuring performance reliability and durability, yet they result in a steeper upfront investment. This cost factor can be a significant barrier to adoption, particularly in price-sensitive markets or in settings where funding is limited.

**Limited Battery Range for Long-Distance Travel:** Despite the advantages of electric propulsion, battery life remains a critical challenge. The energy density of current battery technologies limits the operational range, which might not be sufficient for long-distance travel without frequent recharging. Although regenerative braking and hybrid modes help extend battery usage, the fundamental constraint of battery capacity continues to necessitate further research and innovation in energy storage systems. Improving battery performance and reducing energy consumption without sacrificing power remains a key area for ongoing development.

### Design Limitations

In addition to technical issues, the design of Solar Powered E-Bicycle brings its own set of limitations that can affect overall usability and manufacturability:

**Weight of the Bicycle Due to Added Components:** The inclusion of electric motors, a sizable battery pack, and additional control and sensor systems significantly increases the overall weight of the bicycle. This added weight can impact the handling and maneuverability, especially in Manual Mode where rider effort is the primary means of propulsion. While materials and design optimizations (such as using lightweight alloys or composite materials) can alleviate some of this burden, there remains a trade-off between functionality, durability, and weight minimization.

**Complexity of Integrating Multiple Systems:** The ambition to blend Manual, Electric, and Hybrid modes into one cohesive system introduces substantial complexity. Integrating mechanical drivetrain components with electronic control systems demands meticulous synchronization and precision engineering. The challenges include ensuring smooth transitions between modes, maintaining reliable communication between sensors and the control unit, and providing a user-friendly interface for mode selection. Such complexity not only increases the design and manufacturing time but also requires rigorous testing to eliminate potential points of failure.

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## FUTURE SCOPE :

### Smart Features and IoT Integration :

Integration of GPS tracking, mobile app connectivity, battery monitoring, and speed control systems can make solar bicycles more intelligent and user-friendly.

### Enhanced Energy Recovery Systems:

Further improvements in regenerative braking and energy recovery mechanisms can be pursued. More efficient conversion systems would capture a larger portion of kinetic energy during braking, thus extending the operational range and reducing energy losses.

### Incremental Upgrades to Control Mechanisms:

Even though the current design does not incorporate smart features, future iterations might consider adding basic monitoring features using cost-effective solutions such as simple onboard digital displays. These displays can provide essential information like battery level and speed without resorting to complex IoT systems.

### Cost-Effective Customization:

With a focus on using readily available materials and proven manufacturing techniques, future projects could also explore customizable features that allow end-users to adjust the performance parameters based on their local conditions and usage requirements—all while keeping the design accessible and economical.

### Lightweight and Smart Design

Future models can use lightweight materials like aluminum or carbon fiber to reduce weight and increase speed and efficiency.

The future scope for the Multi-Driven Electric Bicycle is broad and promising. By focusing on improvements in battery technology and exploring refinements in material selection and manufacturing techniques, future iterations of the bicycle can achieve better performance, extended range, and enhanced efficiency. Although the current project utilizes a second-hand stainless-steel frame and avoids complex smart features.

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## CONCLUSION

The design and fabrication of the Solar Powered E-Bicycle represent a paradigm shift in the realm of sustainable, hybrid mobility solutions. The solar powered bicycle is an innovative and eco-friendly transportation system that uses solar energy as its main power source. By converting sunlight into electrical energy through solar panels, the bicycle can charge its battery and power the motor for movement. This project has not only resulted in a uniquely adaptable bicycle but has also provided critical insights into integrating multiple propulsion modalities while prioritizing environmental and economic sustainability. Addressing the high component costs, enhancing battery performance, reducing overall weight, and simplifying the integration of various systems will be pivotal. Mitigating these issues through continued research and technological innovation is essential for advancing the reliability, efficiency, and market readiness of such an innovative transportation solution.