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Solar-Powered Hybrid Bicycle Technology and Its Impact

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Abstract— **The This paper explores the emerging field of solar-powered hybrid bicycle technology, examining current innovations, technical challenges, and future prospects. As urban areas face increasing congestion and environmental concerns, solar hybrid bicycles represent a promising solution that combines human power, electric assistance, and renewable energy. This review analyzes the state-of-the-art in solar integration with bicycles, including photovoltaic technologies, energy storage systems, power management algorithms, and design considerations. Performance metrics from existing prototypes are evaluated against conventional e-bikes and traditional bicycles. The paper concludes by identifying critical development pathways and research opportunities that could accelerate market adoption and enhance the sustainability profile of personal transportation. By analyzing their adaptability, energy efficiency, and appeal to diverse users, this study underscores the potential of solar-powered hybrid bicycles as a transformative innovation in personal mobility.**

Keywords ; Hybrid Bicycle, Direct Current Motor (DC Motor), Solar Panel, Throttle.

I. INTRODUCTION

The Transportation accounts for approximately 23% of global energy-related greenhouse gas emissions, with personal vehicles representing a significant portion of this contribution (IEA, 2023). As urban centers worldwide experience population growth and increasing congestion, there is an urgent need for sustainable transportation alternatives that reduce environmental impact while maintaining personal mobility.

Bicycles have long been celebrated as an efficient and clean transportation mode, with electric bicycles (e-bikes) gaining substantial market share in recent years due to their ability to extend cycling range and make cycling more accessible to diverse populations. However, conventional e-bikes rely on grid electricity, which may still derive from fossil fuel sources depending on the regional energy mix.

Solar-powered hybrid bicycles represent an evolution in sustainable personal transportation by combining three power sources:

Human power through traditional pedaling
Electric assistance via battery-powered motors
Solar energy captured through integrated photovoltaic (PV) panels

This integration creates a transportation solution with potentially zero direct emissions during operation, extended range compared to conventional bicycles, and reduced dependency on grid charging compared to standard e-bikes. The technology aligns with multiple United Nations Sustainable Development Goals, including Affordable and Clean Energy (Goal 7), Sustainable Cities and Communities (Goal 11), and Climate Action (Goal 13).

This paper provides a comprehensive review of the current state of solar-powered hybrid bicycle technology, examining technical components, integration challenges, performance capabilities, and future research directions.

.WORKING PRINCIPLE

The working principle of this model/project “Hybrid Bicycle”is based on the concept of using solar energy for charging batteries of the bicycle by using solar (in addition to AC wall charger) with the help of solar panels. Charging batteries with solar energy reduces the battery charging time and also reduces the charging cost. When sunlight strikes the solar panel, solar energy gets converted into electrical energy by a photovoltaic effect. This electrical energy gets stored in the batteries in the form of electrochemical energy through chemical reactions. This energy is used to run the geared DC motor which in turn runs the bicycle. Components of Hybrid Bicycle: DC motor, battery, solar panel, controller, metal frame, throttle and chain.

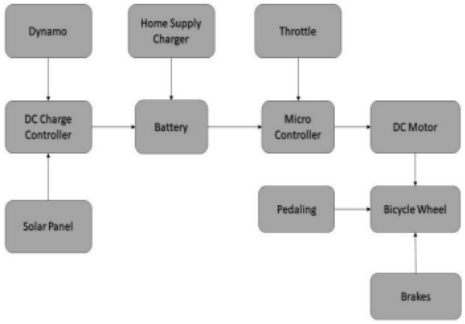

Fig-1: Flow Chart of Solar operated Hybrid Bicycle

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II. Review Of Literature

The According to Mayur Parmar et al.[1], a solar powered bicycle runs at an average speed of fifteen kilometre per hour and the maximum speed is twenty five kilometre per hour with the help of pedalling. They have accentuated that, the battery is charged in twofold manner and also with the help of solar or electrical energy. Their findings also show that the cost of solar powered bicycle is less Rupees Twenty thousand. They concluded that solar powered bicycles are Eco – approachable with negligible pollution.

Kartik S Mishra et al. [2] developed a solar hybrid bicycle. They have found that Hybrid bicycle conglomerates with the use of solar energy and a dynamo. Also they have concluded that, the solar hybrid bicycle can become a very cardinal alternative to the fuel operated automobile and hence its production is essential.s respectively.

Prabhu Randhir et al. [3] designed and upgraded the regular bicycle and made it more efficacious. The bicycle is the combination of electrical energy and pedal operated. They revealed that the required power and the no load speed of the bicycle is 391.61 watts and 20.66 Km/hr respectively.

A. Muetze et al. [4] evaluated the performance of electric bicycles with important parameters.The parameters considered in their study are trends and regulations in market, attracting the customers by improving the designs and reducing the weight of the product.

According to A Karthi et al.[5], the most vibrant characteristic of the electric bike is that it does not use fossil fuels and pollution is reduced. Secondly, it is pollution free, sustainable and soundless in process. It can be charged with the assistance of adapter using alternating current. They concluded that the operating cost of the electric bike is low and further the cost can be reduced by mounting solar panel. Also they found that dis-assembling and maintenance of such bike is easy as it has less number of components.

Fabian Fogelberg [6], performed energy calculations on solar powered E-bikes. The studyrevealed that by placing 0.2-0.8 m2 solar panels per bike on the station's rooftop will supply sufficient energy and also increasing the solar panel area, increase in electric energy production can be seen.

According to Göran Smith et al. [7] pollution is reduced and energy consumption is low in ebikes. They also revealed that by introducing e-bikes large amount of energy can be saved and dependency on fuelled vehicles can be reduced.

According to Dr. K. Hema Latha [8], solar powered vehicles are pollution free and solar energy is abundantly available. The product cost is relatively cheap and the design and construction is simple. She concluded that with fully charged the range is fifty kilometres or runs for four hours with an average of thirty five kilometres per hours.

III. Design and Technology of Solar-Powered Hybrid Bicycles

Frame and Geometry

Solar-powered hybrid bicycles retain the lightweight, versatile frames of traditional hybrids, typically made from aluminum, carbon fiber, or steel alloys. The frame design accommodates solar panels and associated electrical components without compromising aerodynamics or rider comfort. Material Choices: Aluminum ensures a lightweight, durable frame, while carbon fiber is used in premium models for enhanced strength-to-weight ratios.

Geometry: A relaxed head tube angle (70-72 degrees) and longer wheelbase provide stability, ideal for urban and light off-road use

A) Solar Panel

A solar panel is a device that is based on the principle of photovoltaic effect and it is also known as a photovoltaic (PV) panel. Used to convert sunlight into electricity. It is a semiconductor device usually made of silicon. Germanium, Phosphorus, and Indium are commonly used for doping in semiconductor material.\

Table -1: Solar Panel Specifications

Maximum power	50 W
Open circuit voltage	22 V
Short Circuit current	3.1 A
Maximum power voltage	18 V
Maximum power current	2.78 A

Fig-2: Solar Panel

B) BDC Motor

A brushed DC electric motor is a type of motor that ses direct current to create movement. They were the first ype of electric motor to be used commercially to power machines and were used in buildings for over 100 years. Brushed DC motors can change speed by adjusting the voltage or magnetic field strength. Depending on how the motor is connected to the power supply, it can aintain a steady speed or adjust its speed based on how much force it's working against. To control the speed, you can adjust the battery or power supply, use esistors, or electronic controls. You can change the direction of the motor by reversing the connections of

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the field or armature, but not at the same time. This is typically done with special contactors. A permanent magnet DC motor has a quadratic relationship between its speed and torque, where the torque is highest when the motor is not moving, and the speed increases as the load decreases.

Fig-3:BLDC Motor

C) Motor Controller

This solar hybrid bike system includes solar panels, a battery and a brushless dc motor, so a controller is needed to regulate each of the various bike system components. This controller has a variety of uses, including driving and controlling Brushless DC motors as well as protecting against low voltage and high current. Different signals, such as current detection signals, motor speed control signals, and capacity detection systems, were transferred to pins on the controller to drive and regulate brushless dc motors

Fig-4 Controller

D) Battery

A battery is a device that is used to store electrical energy in the form of chemical energy through chemical reactions. it mainly consists of one or more electrochemical cells, electrolytes, and, two terminals (positive(anode) and negative(cathode)). When a battery is connected to an external circuit, a chemical reaction takes place in the cell, which causes electrons to flow from the negative terminal to the positive terminal and generate an electric current.batteries are mainly used to power many devices, from small electronic gadgets like laptops, study lamps, and smartphones to larger applications like vehicles and backup devices. Two dry rechargeable batteries of 12v, 8Ah are used which are connected in series position

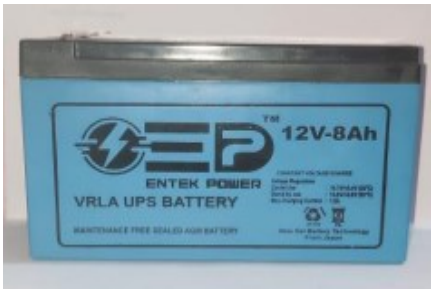

Fig-5: Battery

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E) DC Charge Controller

A charge controller or regulator is a voltage or current regulator to avoid/prevent batteries from overcharging. It regulates the output voltage and current of the solar panel going to the battery. Mostly “12-volt” panels gives an output of around 16-20 volts, if there is no regulation of panel output then batteries will get damaged by overcharging. Boost converters are devices that are used for steeping up voltages in many applications where voltage needs to be increased without conversion into Alternating Current (AC),with the use of transformer and then passing transformer output through a rectifier.

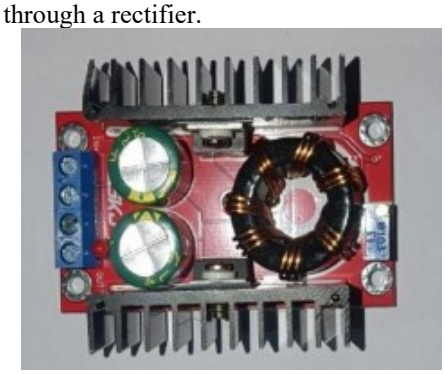

Fig-6: DC Charge Controller

IV. DESIGN CALCULATIONS

No Load Speed Calculations

A: Number of teeth on smaller the sprocket(motor)(t1) = 9 Number of teeth on larger the sprocket (Bicycle)(t2) = 18 Speed on smaller sprocket (motor)(N1) = 3300 rpm By using reduction ratio (9.78), speed will be reduced to 338 rpm Speed on larger sprocket (bicycle)(N2) =?

Using speed ratio formulae, N1t1=N2t2 388*9=N2*18 N2= (388*9)/18 N2=169 rpm

Diameter of wheel = 560mm Circumference of wheel = 3.14*560 = 1758.4mm

Speed of the vehicle = speed of wheel*circumference of wheel = 169*1758.4 = 297169.6 mm/min = 297 m/min = 17830 m/hour = 17.83 km/hour

.Power Required To Drive Bicycle

Total load acting on bicycle are as follows Normal weight of the person = 78.75kg = 78.75*9.81 = 772.54 N Weight of bicycle = 12kg = 12*9.81 = 117.72 N

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Other miscellaneous load = 21.5kg = 21.5-*9.81 = 210.92 N Total load = (772.54+117.72+210.92) = 1101.12 N

To find reaction on each wheel, the above total load which is divided equally on both wheels Force (Ffw) = Force (Frw) = 1101.12/2 = 550.6 N Where the reaction on rear and front wheel are as follows Rfw=Rrw = 0.2*550.6 = 110.12 N
To find torque on each wheel Total torque = Tfw + Trw
To find torque on front wheel Tfw= Rfw*(D÷2) Tfw = 110.12*[(56*10-2) ÷2] Tfw = 30.84 Nm Tfw=Trw= 30.84 Nm Total torque on wheel = 30.84*2 = 61.68 Nm

Battery Charge Time From Solar

You have a 50-Watt, 18-Volt panel and 8Ah, 24 Volt battery bank, how long does it take to completely charge? The quick answer would be to figure out the Watt-hours of the battery (24*8Ah= 192-Watt hours) and divide it by the solar output. The reality is about 1.5 times longer. There are mainly three reasons for the differences, even in ideal conditions. First, the Watt-rating of the panel is the product of the peak current and the open circuit voltage. When we connect a panel to a battery, the voltage drop takes place to that of the load. Finally, all the power that enters the battery does not gets converted into storage energy. In field test, we are seeing that the combined loss factor is about 1.5. Divide the watt hours of the battery by the wattage of the panel and multiply by 1.5. In our project: Watt Rating of battery = 192 Watt Wattage Rating of panel = 50 Watt Charging Time= 1.5*(Watt Rating of battery/ Wattage rating of panel) = 1.5*192/50 = 4 hours and 36 Minutes This calculated charging could increase in cloudy weather, if panel is not pointed at t

Design

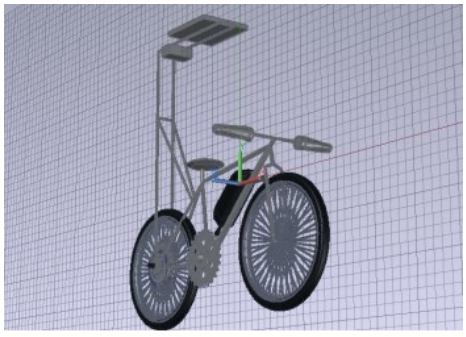

Fig. 7 Isometric view of Solar powered bicycle

V. CONCLUSION

Solar-powered hybrid bicycle technology represents a promising evolution in sustainable personal transportation, combining the inherent efficiency of human-powered mobility with electric assistance and renewable energy generation. Current prototypes have demonstrated the technical feasibility of this approach, with solar contributions typically providing 15-60% of total energy requirements depending on design and usage patterns.
Challenges remain in terms of cost, weight optimization, and all-weather reliability, but ongoing advances in photovoltaic efficiency, battery technology, and system integration are steadily improving performance metrics. The multidisciplinary nature of these challenges presents rich opportunities for research collaboration across materials science, electrical engineering, mechanical design, and human factors.
As urbanization continues and cities worldwide seek solutions to congestion and emissions challenges, solar hybrid bicycles offer a compelling option that aligns with broader sustainability goals. With appropriate technological development and supportive policy frameworks, these vehicles have the potential to contribute significantly to personal mobility while minimizing environmental impact. Advancements in solar-powered hybrid bicycles are promising:
High-Efficiency Panels: Emerging PV technologies, such as perovskite solar cells, could increase energy conversion rates beyond 25%. Lightweight Components: Innovations in battery and panel design aim to reduce weight without sacrificing power output.
Smart Systems: Integration with IoT devices for real-time energy management and route optimization.
E-Hybrid Synergy: Combining solar power with pedal-assist motors to extend range and reduce rider effort.

Applications and User Demographics
Solar-powered hybrid bicycles cater to:Urban Commuters: Seeking sustainable, self-sufficient transport with integrated device charging.Eco-Conscious Cyclists: Prioritizing renewable energy for recreational or fitness rides.Remote Travelers: Using solar power for extended trips where traditional charging infrastructure is unavailable.
Their renewable energy capabilities make them ideal for users seeking autonomy and environmental responsibility.
Advantages

1. It is environment friendly with no use of any fuel.
2. Removal batteries can be taken inside the house for charging.
3. Not dependent on other forms of energy and solar energyis a renewable form of energy.
4. Hybrid bicycles are easy to operate.

Disadvantages

1. The Price of batteries, motors, and solar panels increases with the increase in energy demand of consumers.
2. Solar panels fail to charge battery at night and its efficiency gets reduced in cloudy weather.
3. Increased weight of the bicycle.
4. High initial cost.

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