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Electric Bicycle Conversion Kit

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Abstract: Electric bicycle (e-bike) conversion kits offer a new approach to sustainable urban transportation by converting conventional bicycles into electric-assisted bicycles. This paper examines the components, functionality and benefits of these kits which include an electric motor, battery and control system. By converting kinetic energy from pedaling into electrical energy stored in a battery, these kits improve cycling efficiency and extend travel range, making e-bikes an accessible option for a wider audience. The analysis highlights the potential of conversion kits to reduce urban traffic congestion, reduce carbon emissions and provide a cost-effective alternative to fully electric bicycles. However, the paper also considers technical and regulatory challenges that may hinder widespread adoption. Ultimately, the study emphasizes the role of electric bicycle conversion kits in promoting eco-friendly travel and suggests areas for future research such as better energy storage and smart technology integration to improve their appeal and functionality.

Index Terms **- E-bike conversion kit, pedal power, Electrical energy, BLDC Motor, Lithium-ion battery**

I. INTRODUCTION

1.1 BACKGROUND AND MOTIVATION:

Amid growing environmental concerns and urban congestion, the search for sustainable transportation solutions has become imperative. Electric bicycle conversion kits have emerged as an innovative solution, converting conventional bicycles into electric-assisted varieties, thereby bridging the gap between environmental friendliness and travel comfort. This project examines the potential of these kits to redefine urban mobility, providing an accessible, efficient and green alternative to conventional motorized transport.

1.2 OBJECTIVES:

The main objective of this project is to develop and assess a system that captures and converts pedal power into electrical energy, stores this energy in a battery, and uses it to power an electric motor for bicycle propulsion on-demand. Specifically, the project aims to:

- Design an efficient mechanism for capturing kinetic energy from pedaling and converting it into electrical energy.
- Evaluate the storage capacity and efficiency of batteries used to store the generated electrical energy.
- Explore the feasibility of using the stored energy to power an electric motor, enhancing the bicycle's functionality as a hybrid e-bike.
- Investigate the practical implications of this system in terms of user experience, sustainability, and urban mobility.

1.3 DESCRIPTION:

This project centers on an innovative approach to sustainable transportation by integrating a pedal- powered energy generation and storage system into traditional bicycles. By equipping bicycles with technology to convert pedal power into electrical energy, this project seeks to bridge the gap between manual cycling and electric biking. The project involves designing a conversion kit that includes an energy conversion mechanism, a battery storage unit, and an electric motor, all seamlessly integrated to maintain the bicycle's usability and aesthetics. The system aims to provide cyclists with the option to engage the motor for assistance, leveraging the energy they've generated through pedaling, thereby offering a customizable and efficient mode of transportation.

1.4 FOCUS OF THE PROJECT:

The project's focus areas are crafted to comprehensively understand and optimize the pedal-powered energy conversion system for bicycles:

- **Energy Conversion Mechanism:** Detailed exploration of the technology used to convert kinetic energy from pedalling into electrical energy, focusing on efficiency and integration with the bicycle's existing mechanics.

- **Battery Storage:** Examination of the battery technology used to store the generated electrical energy, including capacity, charge cycles, weight, and integration within the bicycle frame.
- **Motor Utilization:** Analysis of how the stored electrical energy can be effectively used to power an electric motor, including considerations for power output, control systems, and user interface for engaging the motor.
- **Sustainability and Efficiency:** Assessment of the system's environmental impact, particularly in terms of energy efficiency and potential to reduce carbon emissions compared to traditional e-bikes and motor vehicles.
- **User Experience and Urban Mobility Impact:** Evaluation of how the conversion system influences user experience, including ease of use, reliability, and impact on cycling habits, as well as the broader implications for urban mobility and infrastructure.

II. HARDWARE COMPONENTS

Electric bicycle conversion kit consists of major components like BLDC motor, Lithium-ion battery, Toggle switch, PCB circuit, 7812 voltage Regulator IC, MOSFETs, Resistors, Capacitors, Heat sinks. A brief description of these components is presented in this section.

2.1 12v BLDC Motor

The 12V Brushless DC (BLDC) motor serves as the propulsion system for the electric bicycle. It operates at 12 volts and offers efficient power delivery with minimal maintenance. The motor is compact, lightweight, and provides smooth and quiet operation.

2.2 Lithium-ion Battery Pack

The lithium-ion battery pack stores the electrical energy generated by pedalling. It provides a high energy density, allowing for extended riding range without adding significant weight to the bicycle. The battery pack is rechargeable and offers a long cycle life, making it ideal for use in electric vehicles.

2.3 Toggle Switch

The toggle switch is a simple on/off switch used to activate and deactivate the motor system. It provides a convenient way for the cyclist to control the electric assist functionality of the bicycle. The toggle switch is durable, easy to operate, and can withstand outdoor conditions.

2.4 PCB Circuit

The Printed Circuit Board (PCB) is a custom-designed circuit board that integrates various electronic components. It provides a compact and organized platform for connecting and controlling the motor, battery, switch, and other components. The PCB circuit ensures efficient power distribution and reliable operation of the electric bicycle conversion kit.

2.5 7812 Voltage Regulator

The 7812 Voltage Regulator IC regulates the input voltage to a stable 12 volts, ensuring consistent power supply to the motor and other components.

2.6 MOSFETs

The system utilizes Metal-Oxide-Semiconductor Field-Effect Transistors (MOSFETs) as switches in the energy conversion circuit. These components are crucial for efficiently controlling the flow of electrical energy from the pedal power generator to the battery storage unit. Their high switching speed and efficiency minimize energy losses during the conversion process, contributing to the overall efficiency of the system.

2.7 Resistors

Resistors in the circuit serve to control the current flow and stabilize the voltages, ensuring the safety and reliability of the energy conversion process. They play a vital role in protecting sensitive components from potential overcurrent conditions.

2.8 Capacitors

Capacitors are used to smooth out fluctuations in the electrical output from the pedal power generator. This results in a more stable and consistent charge being delivered to the battery, enhancing the longevity and reliability of the energy storage system.

2.9 Heat Sinks

Given the energy conversion process's potential to generate heat, especially in the MOSFETs, heat sinks are integrated into the design. These components effectively dissipate heat away from critical components, maintaining optimal operating temperatures and safeguarding the system's integrity.

III. CALCULATIONS AND ESTIMATIONS

For single-speed bicycles, the distance covered with one rotation of the crank depends on both the crank length and the gear ratio, which in turn depends on the size of the chainring and the rear sprocket. Since we don't have specific information on the chainring and sprocket sizes, let's use a common setup for a single-speed bike as an example:

Chainring size: 44 teeth

Rear sprocket size: 16 teeth

The gear ratio can be calculated as the number of teeth on the chainring divided by the number of teeth on the rear sprocket:

Gear Ratio = Chainring teeth / Rear Sprocket teeth

= 44 / 16 = 2.75

Let us assume that D_{wheel} is the diameter of the wheel and d is the distance covered by one rotation of the crank in meters. C_{wheel} is the circumference of the wheel.

If D_{wheel} = 0.7m, then,

$C_{wheel} = \pi * Dwheel = \pi * 0.7 \approx 2.2m$

d = Gear ratio*Cwheel ≈ 6.0476m

To calculate the mechanical work done by the cyclist, we can use the basic physics formula for work:

$$W = F \times d$$

where:

W is the **work done**,

F is the **force applied,** and **d is the distance** over which the force is applied.

Assume F=100N. We know that d=6.0476m, the work done is given by

W = F×d = 100×6.05 = 604.76J

When the energy generated by the cyclist's pedal strokes is transferred to a motor functioning as a generator with a rating of 12V and 100W, and assuming the generator's efficiency is 80%, we need to consider how much of the mechanical energy is converted into electrical energy.

Let Electrical energy output be E_{out}

- The work done per pedal stroke (mechanical energy) is approximately 604.76 Joules.
- The generator efficiency (η) is 80% or 0.8.

The electrical energy output from the generator can be calculated using the efficiency formula:

E_{out} **=Mechanical Energy Input(W)×η** = 604.76×0.8 = 483.81 J

Assuming the battery charging efficiency to 90%,

Energy stored by the battery in Joules = $E_{out} \times 0.9$ = 435.42 J

Given the battery has a capacity of 3.6Ah, we can adjust the calculation to determine the energy required to charge this specific battery by 1V. The capacity in ampere-hours (Ah) can be converted to charge in coulombs (since 1Ah equals 3600 coulombs), and then we can use the formula:

$$E = V \times Q$$

where: E is the energy in joules,

V is the voltage increase (1V in this case), and

Q is the charge in coulombs, derived from the battery's capacity.

Given the 3.6Ah capacity, the charge

Q=3.6Ah×3600

Then, the energy required for a 1V increase is:

E=1V×Q ≈ 12960 J

Upon calculating the energy required for this battery to charge a 12V Li-Ion battery with a capacity of 3.6Ah by 1V, it would take approximately 12,960 joules of energy.

The number of pedal strokes required to charge the battery by 1V is given by,

Number of Pedal Strokes = Energy required for 1V increase energy stored per pedal stroke = 12960/435.42

= 29.76

Distance to be covered to charge the battery by 1V = 29.76×6.0476 ≈ 180 m

Battery Capacity (Wh)=Battery Voltage (V)×Battery Capacity (Ah)

Battery Capacity (Wh)=12V×3.6Ah = 43.2 Wh

The duration for which the motor can run on this battery can be calculated by dividing the total energy available in the battery by the power draw of the motor:

Motor power(W) = 100 W

Motor Run Time (hours) = Battery Capacity (Wh) / Motor Power(W) = 43.2 □*h* / 100□

= 0.432 hrs

= 29 min

IV. CIRCUIT DESIGN AND WORKING OF CIRCUIT

4.1 CIRCUIT DESIGN

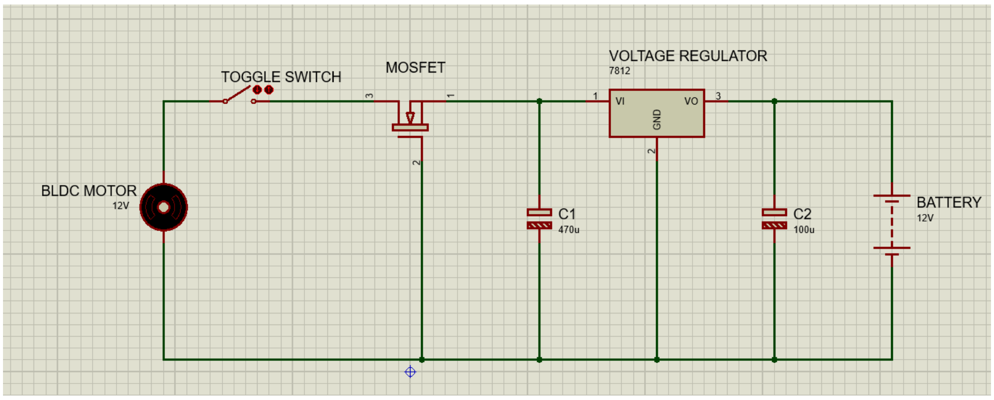


Fig.1. Circuit diagram

4.2 WORKING OF CIRCUIT

In an electric bicycle conversion kit, each component plays a key role, working in harmony to enhance the traditional cycling experience with electric power.

Starting with the 12V BLDC motor, this part is a key part of the conversion kit. Originally designed to propel the bike forward while under power, it acts as a generator in reverse during pedaling. A BLDC motor stands out for its efficiency and durability as it operates without the friction and wear associated with traditional brushed motors. Its brushless design ensures a smooth ride with low maintenance, making it an ideal choice for converting kinetic energy into electrical energy.

A 12V Lithium-ion battery pack acts as the system's energy reservoir. A series of 3.7 V batteries is used to achieve this voltage. Known for its high energy density, this type of battery can store significant amounts of energy without significantly increasing the bike's weight, which is a key factor in maintaining the bike's maneuverability. The rechargeable nature and long lifespan of lithium-ion batteries make them a sustainable choice, able to support many rides that require replacement.

A toggle switch provides direct control of the electric assist system. Placed within easy reach, it allows the motor to be effortlessly turned on for assistance to the cyclist or turned off for manual pedaling. This simple yet effective mechanism ensures that the transition between powered and manual modes is seamless, offering flexibility based on rider needs or terrain.

A PCB (Printed Circuit Board) circuit is the electronic backbone of a system, connecting and managing all electrical components. It orchestrates the flow of power from the pedal generator to the battery and motor, ensuring efficient power delivery. The compact design of the PCB keeps the conversion kit inconspicuous, preserving the bike's aesthetic and functional integrity.

Embedded on the PCB, the 7812 voltage regulator ICs are critical for maintaining stable power delivery. Ensuring that the motor and other components receive a constant 12V supply protects them from potential damage caused by voltage fluctuations, much like a constant regulator that ensures proper performance under varying conditions.

MOSFETs (metal-oxide-semiconductor field-effect transistors) are used as efficient switches in the circuit. Their role is to modulate power from the battery to the motor, allowing precise control of motor speed and torque. Their fast-switching capability and efficiency minimizes power loss, contributing to the overall performance of the kit.

Resistors and capacitors in a circuit are used to stabilize current and voltage. Resistors ensure that the current flowing through the circuit remains within safe limits, while capacitors smooth out any electrical noise or fluctuations, ensuring a constant supply of power to the motor for a smooth ride.

Finally, heat sinks are integrated to manage the thermal output of the system. Components such as MOSFETs can generate significant heat, especially under high loads. Heat sinks absorb and dissipate this heat, preventing overheating and potential damage to the system, ensuring reliability and longevity.

Together, these components form a cohesive system that enhances the traditional bicycle with electric power, providing riders with an efficient, reliable and comfortable mode of transportation.

V. BENEFITS OF THE E-BIKE CONVERSION KIT:

The development and implementation of a pedal power conversion system for electric bicycles bring a myriad of benefits, ranging from environmental to social and economic advantages. Here's a detailed exploration of these benefits:

Environmental Benefits

- By supplementing or replacing motor vehicle use, e-bikes with pedal power conversion kits significantly reduce carbon dioxide and other harmful emissions, contributing to cleaner air and a reduction in greenhouse gas levels.
- The system's ability to convert human kinetic energy into electrical energy for later use makes it an exemplar of energy efficiency, utilizing renewable human power instead of relying solely on external energy sources.
- Retrofitting existing bicycles with conversion kits extends the lifecycle of the bicycle, promoting resource conservation and reducing the environmental impact associated with manufacturing new electric or traditional vehicles.

Health and Social Benefits

- The pedal power system encourages cycling by offering an electric assist option, making it easier for people to choose biking over less active modes of transportation, thereby promoting physical health.
- By making cycling less physically demanding, the conversion kit can make biking a more viable option for a broader range of the population, including older adults and those with physical limitations.
- The adoption of e-bikes with pedal power conversion can foster a sense of community among cyclists, promoting shared values of sustainability, health, and active transportation.

Economic Benefits

- Users can save on transportation costs, including fuel, public transport fares, and vehicle maintenance, by adopting e-bikes equipped with pedal power conversion systems.
- E-bikes can contribute to reducing traffic congestion, leading to lower infrastructure maintenance costs and more efficient urban environments.
- The production, installation, and maintenance of pedal power conversion kits can create jobs and stimulate local economies, especially in regions committed to sustainable transportation solutions.

Technological and Innovative Benefits

- The development of pedal power conversion systems can drive innovations in renewable energy capture, storage, and utilization, contributing valuable insights to the broader field of sustainable energy technologies.
- Offering a conversion kit allows users to customize their mode of transportation to their specific needs and preferences, empowering them with a sense of ownership and control over their travel experience.
- The system can be designed to integrate with smart technologies, providing users with valuable data on their travel habits, energy usage, and the environmental impact of their choices, encouraging informed and sustainable decision-making.

Overall, the adoption of pedal power conversion systems in electric bicycles presents a multifaceted solution to modern transportation challenges, aligning with global efforts towards sustainability, health, and economic resilience.

VI. POTENTIAL IMPACT:

Urban Mobility and Infrastructure

- By providing an efficient and viable alternative to cars for short to medium distances, e-bikes can significantly reduce traffic congestion in urban areas.
- E-bikes require less space for parking compared to cars, alleviating pressure on urban parking infrastructures and potentially freeing up space for other uses.
- E-bikes can seamlessly integrate with other forms of public transport, encouraging a more flexible and efficient urban mobility system.

Environmental Sustainability

- The shift from fossil fuel-powered vehicles to pedal-powered e-bikes can lead to a substantial reduction in urban carbon emissions, contributing to climate change mitigation efforts.
- E-bikes are significantly quieter than motor vehicles, contributing to a reduction in urban noise pollution levels.
- The popularity of e-bikes can influence city planning to prioritize cycling infrastructure, green spaces, and pedestrian areas, fostering more sustainable and liveable cities.

Public Health and Wellbeing

- Reduced reliance on motor vehicles can lead to improved air quality, with direct benefits for respiratory health among urban populations.
- The use of pedal power conversion kits encourages physical activity, which can improve cardiovascular health, reduce obesity rates, and enhance overall wellbeing.
- Cycling has been shown to reduce stress and improve mental health, making pedal-powered e-bikes an attractive option for enhancing psychological wellbeing.

Economic Development

- The low operating and maintenance costs of e-bikes, compared to cars and public transport, can lead to significant savings for individuals.
- The growing e-bike industry, including manufacturing, sales, and maintenance of conversion kits, can create new jobs and stimulate economic growth.
- By reducing reliance on imported fossil fuels, pedal power conversion systems contribute to national energy security and resilience.

Technological Innovation

- The demand for more efficient and reliable e-bike conversion kits can drive innovation in battery technology, energy conversion, and smart mobility solutions.
- Integration with IoT and smart devices can provide valuable data on usage patterns, energy savings, and user preferences, informing future urban planning and transportation policies.

Social Equity

- E-bikes can make cycling accessible to a broader segment of the population, including those who may find traditional biking too physically demanding, thereby promoting social inclusion.
- E-bikes can enhance connectivity and mobility options for people in rural and suburban areas, where public transport options may be limited.

By addressing these key areas, the adoption of pedal power conversion systems for e-bikes has the potential to bring about transformative changes, contributing to the creation of more sustainable, healthy, and equitable urban environments.

VII. CHALLENGES AND LIMITATIONS:

While the adoption of pedal power conversion systems for electric bicycles presents numerous benefits, it also faces several challenges and limitations that need to be addressed for widespread acceptance and implementation. Here are some of the key challenges:

Technical and Performance Challenges

- Achieving high energy conversion efficiency and effective energy storage within the compact space of a bicycle frame poses technical challenges, particularly in terms of battery technology and the efficiency of the conversion mechanism.
- Adding a conversion kit can increase the weight of the bicycle and potentially affect its aerodynamics, which could impact the ease of pedaling and overall cycling experience, especially when the electric assist is not in use.
- Ensuring the durability of conversion kit components exposed to various weather conditions and regular wear and tear, as well as ease of maintenance, are critical for user satisfaction and long-term viability.

Economic and Market Challenges

- The initial cost of a conversion kit can be a significant barrier for many potential users, especially when compared to traditional bicycles or even some lower-cost e-bike models.
- Convincing traditional cyclists and new users to invest in conversion kits requires effective marketing strategies and awareness campaigns about the benefits and practicality of e-bike conversion kits.
- The existing urban infrastructure in many cities may not yet be fully equipped to accommodate an increase in e-bikes, necessitating investments in bike lanes, parking, and charging stations.

Regulatory and Safety Issues

- There may be regulatory ambiguities regarding the classification of converted e-bikes, impacting their legal use on roads, bike lanes, and in public spaces.
- Questions around insurance coverage and liability in the event of accidents involving converted e-bikes can pose challenges for users and manufacturers.

Social and Behavioral Barriers

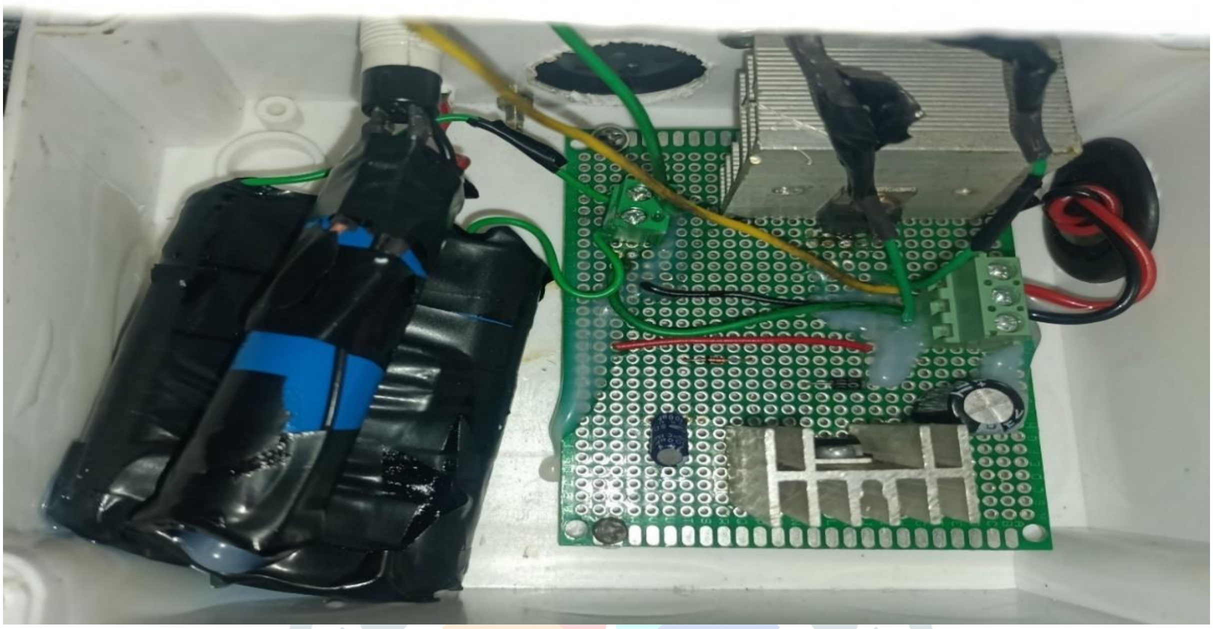
- In some regions, bicycles are seen primarily as recreational or sports equipment rather than viable daily transportation, which can limit the adoption of e-bike conversion kits.
- Convincing traditional cyclists and motorists to switch to e-bikes, even with the added convenience of pedal power conversion, may encounter resistance due to ingrained habits and preferences.
- Ensuring that conversion kits are accessible and appealing to a broad demographic, including older adults, people with disabilities, and those with limited technical skills, remains a challenge.

Environmental Considerations

- The environmental impact of sourcing materials for batteries and other components, as well as the need for responsible recycling and disposal processes, must be carefully managed.

- Comprehensive lifecycle analyses are needed to fully understand the environmental footprint of manufacturing, using, and disposing of conversion kits, compared to other transportation options.Addressing these challenges and limitations requires concerted efforts from manufacturers, policymakers, urban planners, and communities. Innovations in technology, supportive regulatory frameworks, public awareness campaigns, and infrastructure development are crucial for overcoming these barriers and unlocking the full potential of pedal power conversion systems for electric bicycles.

VIII. OUR MODEL:



IX. CONCLUSION:

In conclusion, the development and implementation of pedal power conversion systems for electric bicycles represents a significant stride towards sustainable and efficient urban mobility. By harnessing human kinetic energy to generate and store electrical power, these systems offer a promising solution to reduce carbon emissions, promote physical health, and alleviate urban congestion. The integration of such technology into everyday commuting practices aligns with global sustainability goals, fostering a greener, healthier, and more connected urban environment.

Despite the numerous benefits, the widespread adoption of e-bike conversion kits faces several challenges, including technical limitations, economic barriers, regulatory uncertainties, and social perceptions. Addressing these challenges necessitates a collaborative approach involving innovation in design and technology, supportive policy frameworks, public education, and infrastructure enhancements.

As we move forward, it is imperative to continue refining technology, expanding accessibility, and fostering a cultural shift towards more sustainable modes of transportation. The potential impact of pedal power conversion systems on urban mobility and environmental sustainability is profound, offering a glimpse into a future where transportation is not only about reaching a destination but doing so in a way that benefits our health, community, and planet.

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