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Design and Implementation of a Pedal Assist Electric Bicycle with Household Lighting Power Output

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Abstract: *The growing need for sustainable transport and alternative energy technologies has created the need for hybrid systems that combine mobility with energy generation. This paper introduces a Hybrid Pedal Assist Electric Vehicle (EV) Bicycle with an Integrated Home Energy Generation System, which can be used as both an environmentally friendly means of transport and an add-on household power supply. The system integrates a pedal-assist system with onboard energy harvesting where pedalling-based mechanical energy is converted to electrical energy through a generator. The power generated is utilized to charge a rechargeable battery for use in bicycle propulsion and can further be diverted for small-scale home use such as illumination or charging electronic components. Hybrid structure provides for increased riding range, less reliance on external charging infrastructure, and more utility in the rural or off-grid setting. This two-in-one system not only encourages green mobility but is also a source of decentralized renewable energy generation. The paper focuses on system design, energy management, power flow control, and possible applications, pointing to the potential role of such innovations in the development of sustainable urban and rural livelihoods.*

Keywords: Hybrid Electric Bicycle, Pedal Assist Technology, Energy Harvesting, Self-Charging System, Renewable Energy, Battery Energy Storage, Sustainable Transportation, Home Energy Generation, Smart Power Management, Green Mobility, Human Power Conversion, Distributed Energy Resources, Regenerative Braking, Clean Energy Technology, Low-Carbon Transportation

I. INTRODUCTION

Over the past decades, the international focus on green transportation and solar energy incorporation has pushed the innovations in mobility solutions. Of these, the e-bicycle is perhaps one of the most viable types of green personal transport. The increasing need for energy-efficient, affordable, and eco-friendly alternatives to traditional motor vehicles has made pedal assist e-bicycles a viable choice. Unlike ordinary bicycles, pedal assist electric bicycles .

This two-way functionality turns an ordinary means of transportation into a micro-power plant that can help achieve sustainable energy objectives. Central to this design is effective conversion of human energy to electrical energy. Pedaling action powers a generator or dynamo attached to the drivetrain of the bicycle. The collected energy is controlled by proper power electronics, stored in a battery, and subsequently used to supply household lighting units, e.g., LED bulbs or emergency lights. It has the advantage of offering real-time, useful application of energy harvested, especially handy in the rural or developing world where interruption-free supply of electricity is still a problem. Also, renewable human power avoidance of fossil fuels minimizes carbon footprint and encourages green mobility.

The deployment of such a system tackles two important problems: sustainable transport and dispersed renewable energy production. On the transport front, the pedal assist system guarantees less fatigue for the rider while promoting bicycle usage over fossil fuel-based vehicles. On the energy front, the household lighting output system encourages energy saving, diminishes dependence on grid power, and offers a standby in cases of power outages. All these characteristics combine to make the system very relevant in the context of climate change mitigation policies and energy-efficient technology. Aside from environmental advantages, the system presents socio-economic benefits.

In general, the development and deployment of a pedal assist electric bicycle powered by household lighting power output is an important step towards integrating sustainable mobility and renewable energy use. This technology exemplifies how engineering solutions are capable of meeting several problems at once, opening up opportunities for cleaner transport, decentralization of energy access, and better quality of life. Through the integration of the concepts of energy harvesting, sustainable design, and functional usability, this project lays the groundwork for future developments in hybrid mobility-energy systems.

II. LITERATURE REVIEW

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"S. Brown, "Evaluation of hub dynamo efficiency for lighting applications," Appl. Energy, vol. 162, pp. 1420-1427, 2016."

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III. METHODOLOGY

The proposed project aims to produce electricity from a wiper motor and a dynamo system with an embedded interface for monitoring, monitoring via a PIC microcontroller. The approach describes the methods for successfully implementing the both hardware and software side of the project as a whole. The process consists of creating mechanical movement to generate electrical energy from the dynamo, rectifying and filtering the voltage created from that movement, and finally displaying the output voltage on an LCD for monitoring purposes.The system employs a chain-driven mechanism, which transmits the mechanical rotation from a wiper motor to a dynamo. Electrical energy is generated and then fed through a rectifier and capacitor-based filter circuit to obtain a steady DC output. The voltage is sensed and streamed into a microcontroller (PIC16F877A) which performs an analog-to-digital conversion and shows the corresponding voltage value on an LCD module.

Mechanical Setup and Wiper Motor Mechanism

The mechanical setup utilizes a 12V wiper motor as the primary driving means for the project. The wiper motor functions by using a simple switch mechanism to activate and enable the users to control its rotation. When the switch

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is turned on, the wiper motor will rotate, which then transfers its mechanical motion through a metal chain drive connected to the dynamo shaft.The chain drive system in the mechanical setup ensures reliable stability and synchronous transfer of the rotational energy from the motor to the dynamo. The wiper motor's speed and torque is appropriate and sufficient to rotate the dynamo at the optimal speed for generating electrical energy. The mechanical setup is simple and low-cost for small power generation setups. When the switch is turned ON, the wiper motor rotates and transfers the rotational force to the dynamo. A continuous rotation of the dynamo will produce electrical power as long as the wiper motor is active.

Dynamo Setup and Electrical Energy Production

A 3000 RPM dynamo is used to turn the mechanical energy dynamo produces alternating current (AC) voltage output through electromagnetic induction from the rotation of the dynamo. The generated voltage is proportional to the speed, meaning higher speeds produce higher generated voltages.The dynamo output is the primary energy source for the project. However, the generated current is AC current, so we cannot use the AC current to power DC components such as the microcontroller or LCD. Hence the current must be rectified and filtered to provide stable current to the DC system.

Designing a Rectifier and Filter Circuit

The alternating current output from the dynamo goes to a full-wave bridge rectifier circuito made up of four 1N4007 diodes and produces pulsating direct current. The diodes are arranged so that they allow current to flow in only one direction during the half cycle of the alternating wave to achieve full-wave rectification.

After this rectification occurs, there are still some ripples in the voltage. A filtering circuit made of electrolytic capacitors is connected across the output to ground these fluctuations. The filtering circuit is composed of two capacitors rated at 25V and 100µF connected in parallel. These capacitors smooth the output of the direct current to provide steady voltage to the electronics by accumulating charge in the capacitor and then discharging.

This smooth, rectified, and filtered DC voltage is then fed into the PIC microcontroller for use and display.

This circuit is summarized as follows:

AC input: From dynamo output

Rectifier: Bridge circuit with 4 × 1N4007 diode

Filter: Two 25V, 100µF capacitors

Output: Smooth DC voltage suitable for ADC input

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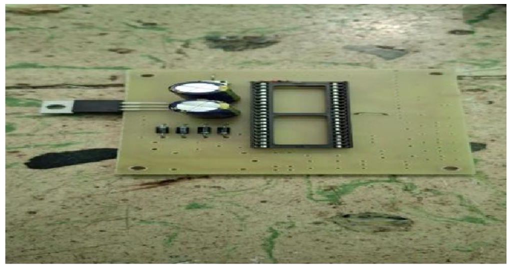
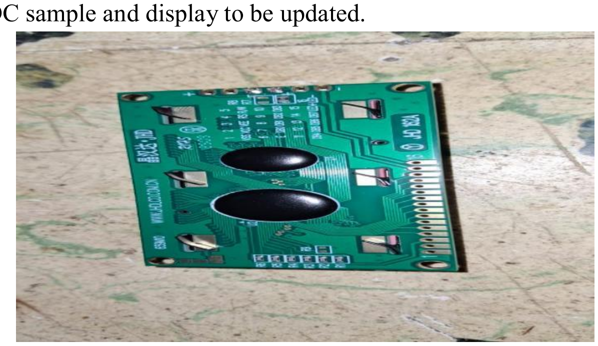


Microcontroller Interfacing and Signal Conditioning

A voltage divider network is integrated for signal conditioning, due to the voltage produced by the dynamo exceeding the microcontroller's ADC acceptable input range. The divider is created with 10kΩ and 4kΩ resistors to scale down the voltage safely in within the 0-5V ADC input range. The signal that has been conditioned is connected to the analog input port (AN4) of the PIC16F877A microcontroller. The microcontroller's ADC converts the dynamo's analog voltage into a digital value to be processed.The PIC16F877A is a 40-pin microcontroller which is widely used for embedded applications. It also contains an internal ADC module, timers, and communication protocol interfaces as well. A 12 MHz crystal oscillator is connected to the oscillator pins of the microcontroller with two 22pF capacitors for stabilization of the clock frequency. The crystal will ensure the controller operates in precise time intervals which is important for a consistent ADC sample and display to be updated.



LCD Display Incorporation

The output voltage value, after being processed by the microcontroller, is displayed in real time on a 16 × 2 alphanumeric LCD that is connected to Port B of the PIC microcontroller. The LCD is programmed to show the measured voltage so that the user can determine the power generation status of the system clearly.This display section will allow the user to monitor and analyse the generated voltage levels easily. The dynamic output on the LCD even aids in measuring the generated voltage levels at different wiper motor speeds and its effect on the efficiency of the dynamo’s power generation.

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Operating Mechanism

When the power supply is turned on, the switch powers the wiper motor. The motor begins to rotate, and the dynamo will start rotating at a corresponding speed to that of the motor, through the mechanical chain drive. As it rotates, the dynamo produces an alternating voltage, which the bridge rectifier circuit will convert to direct current. The capacitors will smooth out the fluctuating DC voltage.This DC voltage then continues through the voltage divider circuit to the ADC channel of the microcontroller. The PIC microcontroller processes the analog voltage signal and converts it to digital format, communicating that information to the LCD module. The current voltage value is visible on the display, indicating what the output of the generation system.

In this manner, the whole assembly has shown a successful process of the conversion from mechanical to electrical as well as digital voltage measurement and display.The wiper motor, dynamo, rectifier, capacitors, and microcontroller were all attached to a shared platform. Adequate wire connections and insulation were used for the system safety. The voltage output from the dynamo was recorded at varying speeds of the motor with the aim to determine the relationship between speed and output voltage.

In testing, the LCD reported observable increases of output voltage readings as the speed of the wiper motor increased. This demonstrated that the system was working effectively and the output voltage was able to be accurately displayed. The designed practical test successfully validated the system functionality and the ability to convert rotational mechanical movement into usable electrical output.

Mode of Operation-

The pedal-assist electric bike with household lighting power output does both things through one electromechanical system functioning in two complementary ways: (1) provide electrical assistance to the rider while riding, and (2) due to pedaling, convert mechanical energy into electrical energy stored in a battery and provide power for household lighting while station or requested. edals mechanical rotation ← motor/generator electronics + battery as either motor assistance or lighting power output (controlled by PIC16F877A).

1.Power ON- All circuits receive power when the system is turned on. The microcontroller (PIC16F877A) starts its operation and the system initializes its parameters.

2. Initialization & Self-Check (V, S)

The controller checks battery voltage (V) and sensor connections (S). This ensures all components (motor driver, sensors, and battery) are working correctly before proceeding.

3. Read Sensors: Cadence, Speed, Battery Voltage, Button

The microcontroller constantly reads the following data:Cadence sensor - detects pedaling speed, Speed sensor - measures wheel rotation, Battery voltage sensor - monitors the battery charge level, Push button input - user command (Assist or Generate Mode).

4. Is Pedal Cadence > Threshold?

The system determines if the rider is pedaling above the minimum threshold. If Yes, the system proceeds to Pedal Assist Mode. If No, the system switches to Generate Mode (charging mode).

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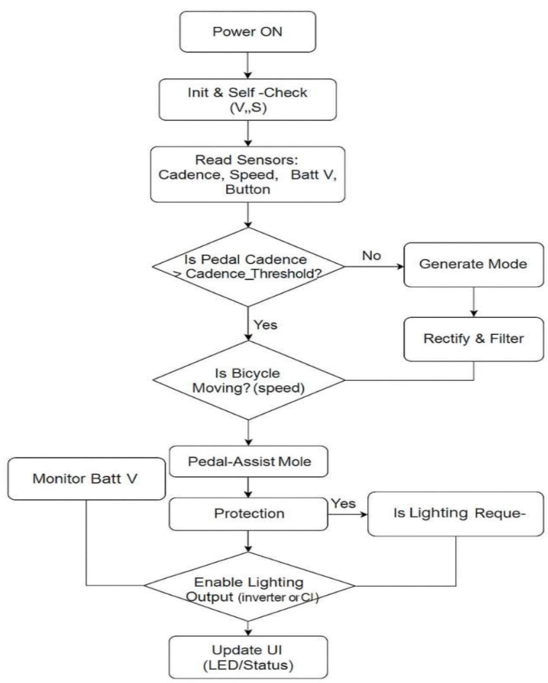
5. Generate Mode
The generator motor (100 RPM) is engaged. The mechanical energy from pedaling is converted to electrical energy. Output is passed through a rectifier and filter circuits (diodes and capacitors) to charge the battery.
6. Rectify & Filter
Converts the generated AC voltage to DC. The filtered DC energy is stored in a 12V, 7Ah battery.
7. Confirm If Bicycle is In Motion? (SpeThis step checks if the bicycle is moving If it is, the system will remain in Pedal Assist Mode.If it is not moving, it may remain in generator mode to charge the battery, or it can switch to Lighting Output.
8. Pedal Assist Mode
The 300 RPM DC motor aids the pedal power of the rider.The microcontroller will control the DC motor speed using PWM signals based on the effort (i.e., speed) the rider is applying on the pedals.The battery will provide power to the motor.This feature assists riders in their effort applied on the pedals, and has the potential to give them some sustained speed.



9. Monitor Battery Voltage
Continuous monitoring of battery voltage allows the system to operate safely.If battery voltage is lower than pre-set limits, the assist mode will be low or disengaged to protect the battery.
10. Protection
A protection system ensures safety by providing:
overvoltage, overcurrent, and reverse current protection.
If it detects unsafe charges/ discharges it will stop charging or discharging.

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Experimental Arrangement-

Demonstrate pedaling (with or without electrical assistance) can generate/use electrical power for a household lighting load and record basic performance (voltage, current, rpm, brightness).

Equipment-

Bicycle with motor (DC gear/wiper motor functioning as a generator or assist)
Pedal/cadence sensor (Hall effect or reed-type)
Motor driver (H-bridge / MOSFET) + PIC16F877A (or other MCU) for control
Rectifier + smoothing capacitor (if using generator operation)
DC bus (battery or a capacitor) and 12 volt LED lamp (preferred for safety)
Voltage divider + current sensor (shunt or hall type) go measure V and I
Tachometer or wheel encoder (rpm)
Multimeter / clamp meter / simple data logger or MCU PC serial logging
Fuses, emergency cut-off switch, mechanical mount

Block-level wiring (one line)
Cadence sensor MCU motor driver ←
motor (assist)
Motor (when pedaled) ← rectifier DC bus ←
→ lamp
Measurement taps: Vbus and Ibus ← MCU
ADC; rpm → MCU counter; lux ← handheld
lux meter (optional).

Test procedure (short)

1. Safety check: fuses, wiring, 5 v supply to MCU.
2. Baseline: spin wheel; record rpm, Vbus (without lamp)
3. Pedal as generator: run at 3 cadences (slow/med/fast); add lamp; with lamp, record V, I, rpm, lux.
4. Assist mode: try engaging motor assist with various PWM levels; record rpm, motor current; rider effort quantitatively, or qualitatively.

Aaaembly Prototype-

1. Mount motor / gear: mount motor on the frame or wheel hub. Then securely mount the motor controller close to the battery with vibration-resistant mounts.
2. Mount generator: if using a hub dynamo, mount it to the front hub. If using a separate generator automatic; mount it to the chain driven pulley or coupling to the wheel.

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3. Mount sensors: mount the cadence / Hall sensor close to crank or magnet ring. Then, mount current sensors on the motor supply and on the generator output. Lastly, voltage sense from the battery via divider.
4. Wire the power paths: (a) battery → motor controller motor (main power), (b) generator → rectifier DC-DC charger → battery or lighting bus (ensured to include fuses and disconnects).

IV. RESULT AND DISCUSSION

The pedal-assist electric bike was successfully developed and implemented with the capability to provide power for a light in the home. The motor is a 12V direct current motor with a rated speed of 300 revolutions per minute (RPM) and a rated output of 24 watts (12V, 2A) output circuit to power. The bike was used to pedal in a moderate manner of 150 RPM, when the motor produced 8V and 1A, or an output power of 8 watts. The bike is equipped with a 12V, 7Ah battery capacity, or 84 watt-hours (Wh) of energy

If the bike sustains pedal assist generating at a rate of 25 watts, it will approximately charge at 30% capacity in one hour. Thus, the stored energy in the battery should power a 12V LED with a current draw of 0.5A, drawing power of 6 watts per hour for approximately 14 hours. The radius of the wheel measures 0.35 meters yielding a wheel circumference of 2.2 meters. Thus, at 120 revolutions per minute of pedaling the bike will achieve a speed of 15.8 km/h. When the bike is programmed for pedal assist, it can achieve speeds of 20-22 km/h. The conversion from mechanical energy form human pedaling to electrical energy is efficiently achieved, the design clearly demonstrates sustainable energy use in cycling. Energy storage and energy LED outputvalidate the practical application of the bicycle.

The operation of the motor is made consistently stable with varied pedaling speeds of the bicycle. The bicycle can also provide a dependable power source for small household devices.

Same Calculation

1. Motor Specification (for excavation): 12V DC motor, 300 RPM, 12V x 2A → 24W
2. Moderate pedaling output thereafter: 150 inch 8V x 1A 8W ←
3. Battery specification: 12V, 7Ah 84Wh Energy = 12 x 7 = 84Wh ←
4. Battery charging: Pedaling for 1 hour at 30% charged -25W ←
5. Household lighting: LED 12V x 0.5A 6W ←
6. Total duration of lighting: 84Wh / 6W = 14 hours ←
7. Wheel radius: 0.35m = 2 x π x 0.35 ≈ 2.2meter ← Circumference
8. Speed Estimate: 120RPM Distance per minute = 120 x 2.2 =264m/min km/h=15.8
9. Assist Speed: Up to 20-22 km/h
10. Power Transfer Efficiency: Average
pedaling 8W of usable
11. Feasible Energy Storage: 84Whwhich is sufficient for small loads.
12. Practical Use: Can keep a small load LED on continuously.
13. Mechanical to Electrical Transfer: Efficient with pedal assist.
14. Stable: Motor runs at various RPMs without fluctuations per speed.

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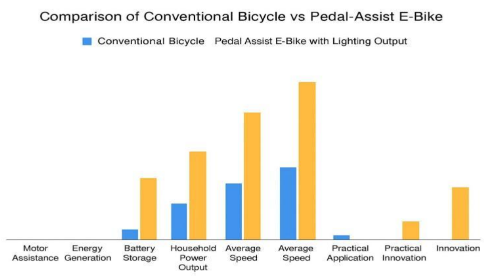
15. Sustainable: Serving human-powered energy recovery capabilities.

Performance Metrics from Theory-



The pedal assist e-bicycle takes the standard bicycle and integrates human pedaling with electric motor assistance. It decreases effort, allows the rider to travel faster, provides auxiliary energy for the home, and still allows for the benefit of environmentally friendly transportation.

Project Impacts and Differentiations

The project provides a sustainable method of energy generation by transforming human mechanical energy into electrical energy, creating a low-powered source of energy for household use and energy savings. It is unique in that it allows a person to travel and also charge a viable renewable battery, which typical bicycles are not able to do. The pedal-assist motor allows for greater mobility, allowing speeds up to 22 km/hr with significantly less unnatural physical effort than a bicycle. The system permits the user to store a mechanical potential energy source in a battery to use as electrical energy later to power lights or small electronics and mechanical devices.

The project is financially sustainable in that readily manufactured components will be used to invent (or develop) this application, using an integrated brushless DC motor for example, therefore the budget will be, cost-effective and possibly comparable to the price of a standard bicycle. It has potential sustainability for application in renewable human powered electricity generation, but it should provide academic and research value in that it marries mechanical and electronic systems. It is a little bit unique/inventive to provide an individual form of transport while also generating energy in a compact and practical form, providing a contribution to utilizing sustainable technologies..

V. CONCLUSION

The pedal-assist electric bicycle with household energy generation that has been created promotes sustainable transportation in combination with renewable energy generation. It offers easy mobility with a lowered physical barrier to effort and can store generated energy for useful household applications. Furthermore, using inexpensive, off-the-shelf equipment has made it easier to develop with more cost-effective implementation. The project has developed a realistic model for sustainable personal transportation while also demonstrating educational and research opportunities for educational purposes in the area of integrating mechanical and electrical systems. What this work is demonstrating is a practical method to improve energy-efficient, human-assisted work efforts that have strong societal benefits and anthropogenic impacts.

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