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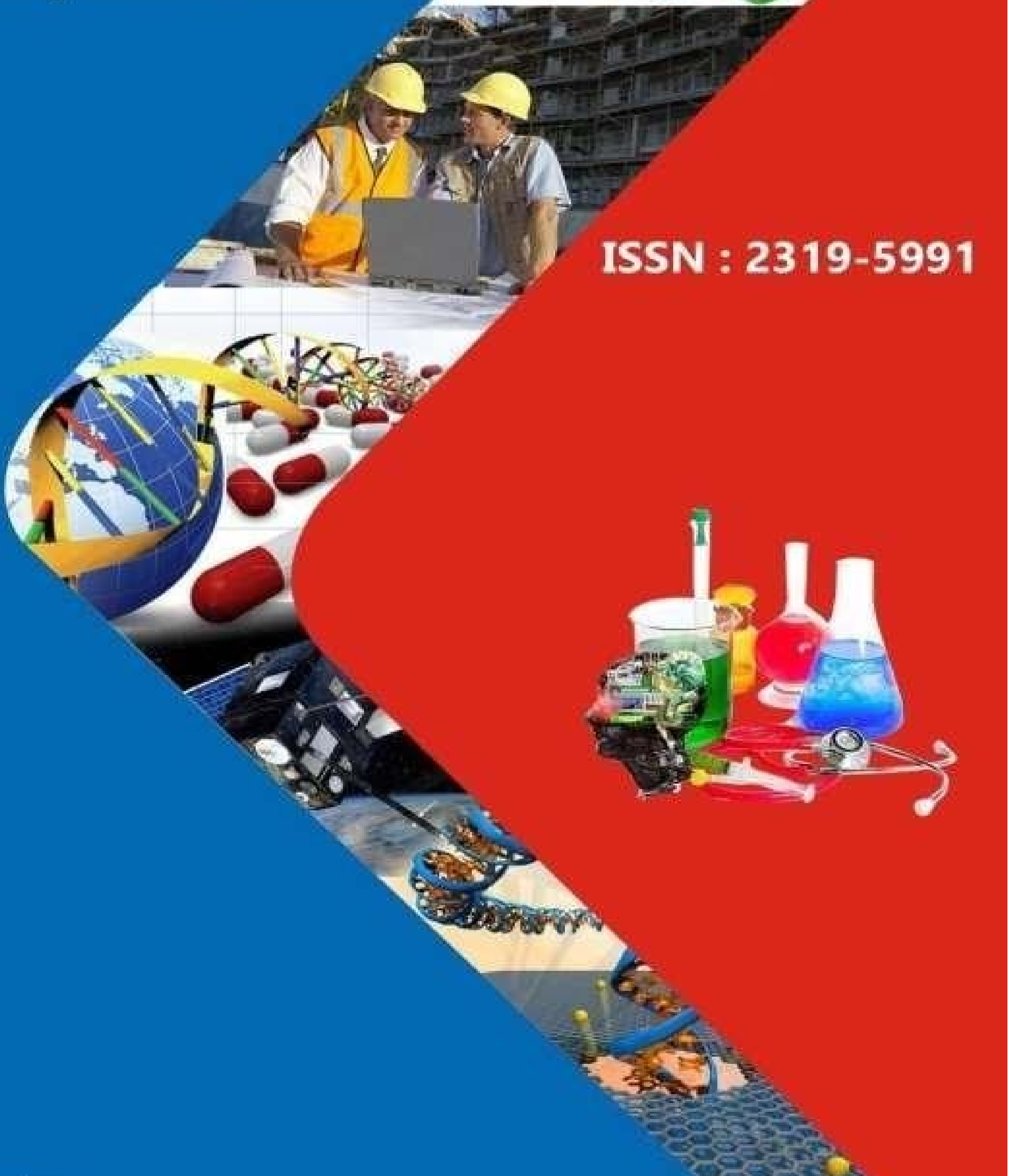

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Regenerative Bicycle integrated with RFID locking GPS Tracking.

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ABSTRACT

This paper presents the design and development of a smart energy-efficient regenerative bicycle integrated with RFID-based locking and GPS tracking technologies. The regenera- tive bicycle is engineered to capture and store kinetic energy generated while riding convert- ing it into electrical energy to recharge an onboard battery, thus enhancing range and reducing rider effort. The integration of an RFID locking system provides enhanced secu- rity, allowing authorized users to unlock and operate the bicycle seamlessly while deterring theft.

GPS tracking functionality enables real-time location monitoring, enabling users to locate their bicycles remotely and aiding in recovery in case of theft. The proposed solution lever- ages IoT-based connectivity for efficient data transmission to a mobile application, giving users access to battery status, route tracking, and real-time alerts. The regenerative bicycle system aims to promote sustainable urban mobility by enhancing the utility, security, and user control.

I. LITERATURE REVIEW

1. Regenerative Braking in Bicycles

Regenerative braking technology has been extensively studied in electric and hybrid vehicles. This technology converts kinetic energy into electrical energy during braking and stores it in a battery for future use. According to regenerative braking in bicycles increases energy efficiency by up to 30%, improving the sustainability of cycling. demonstrated the effectiveness of a hub motor system that captures and stores energy in a lithium-ion battery, which can later be used to assist. Similarly,] proposed a supercapacitor-based storage system that improves energy retention and reduces battery wear. (Ref – 1)

2. RFID Technology for Bicycle Identification and Security

RFID (Radio Frequency Identification) is widely used for automated identification and access control. The implementation of RFID in bicycles has been explored primarily for security and anti-theft applications. Research by highlights the role of RFID in bicycle fleet management (Ref – 2)

3. GPS Tracking for Bicycle Monitoring

GPS technology plays a crucial role in real-time tracking and navigation. Research has shown that integrating GPS with bicycles improves security, fleet management, and user experience. According to GPS-enabled tracking systems reduce bicycle theft by providing real-time location updates. (Ref – 3)

4. Integration of Regenerative Braking, RFID, and GPS

Several researchers have attempted to integrate these technologies into a single bicycle system. developed a combining regenerative braking with GPS and RFID-based authentication. (Ref – 4)

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II. INTRODUCTION

A Regenerative bicycle equipped with RFID locking and GPS tracking combines cutting-edge technology to enhance security, energy efficiency, and convenience for urban mobility. This type of bike not only recovers energy but also incorporates advanced tracking and security features, making it ideal for smart city applications and modern transportation. This integrated system makes regenerative bicycles more practical, efficient, and secure for modern urban settings, supporting both personal and shared mobility solutions.

Regenerative bicycle equipped with RFID locking and GPS tracking is an innovative, high-tech solution designed to enhance both the sustainability and security of urban cycling. This type of bicycle incorporates advanced regenerative technology, which not only powers the bike but also provides features like real-time tracking and secure, contactless locking.

By combining regenerative bicycle, RFID Access, and GPS Tracking, this bicycle technology promotes eco-friendly transportation, enhanced security and smart urban mobility. (Ref – 5)

III. BLOCK DIAGRAM

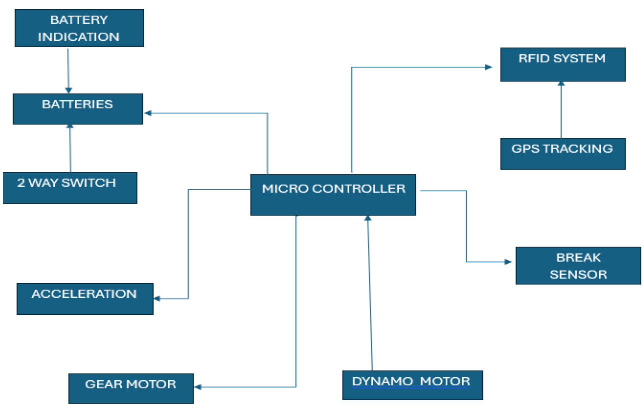

FIG - 1 Block Diagram

IV. METHODOLOGIES

A. Starting and Unlocking with RFID

1. **User Access:** The user approaches the bike and unlocks it using an RFID-enabled device such as a card, key fob, or smartphone with an RFID tag. The RFID reader on the bike scans the tag and checks it against a database of authorized users.

2. **Authentication:** If the RFID tag is valid, the bike's electronic locking mechanism disengages, allowing the bike to be used. This secure, contactless method simplifies access for users in shared bike systems and provides theft prevention by restricting access.

3. **Integration of Regenerative Bicycle in Electric Bicycle :**While the integration of regenerative braking with RFID and GPS technologies in bicycles is still an emerging field, there have been advancements in regenerative braking systems within electric bicycles. These systems capture kinetic energy during cycling and convert it into electrical energy, which is then stored in the battery. (Ref – 6)

B. Real-Time GPS Tracking and Location Monitoring

1. **GPS Module Installation:** A GPS tracker like a SIM based GPS module is embedded in the bicycle's control unit. The mod- ule consists of a receiver that connects to satellites and a transmitter that sends lo- cation data. It is powered by the battery, which is charged using regenerative bicycle. (Ref – 7)

2. **Continuous GPS Tracking:** The GPS tracking system is active while the bike is in motion. It can transmit real-time location data to a connected mobile app or a centralized server, allowing users or fleet operators to locate the bike at any time.

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3. **Anti-Theft Monitoring:** If the bike is moved without being unlocked by an RFID tag, the GPS system can send an alert, indicating potential theft. This feature helps deter theft by ensuring that any un- authorized movement is detected. (Ref – 8)

4. **Usage Analytics and Fleet Manage ment:** GPS data can be used to analyze usage patterns, popular routes, and areas with high demand. For bike-sharing programs, this data helps optimize bike allocation, ensure availability, and improve fleet management.

C. Parking and Locking the Bike

1. **RFID Locking Mechanism:** At the end of the ride, the user locks the bike using their RFID tag. This action secures the bike and logs the end of the session, marking the bike as “parked” in the system. (Ref – 10)

2**. Low-Power Mode:** Once locked, the bike's power system enters a low-energy state, minimizing battery drain while still keeping GPS tracking and RFID reader functionalities active.

3. **Battery Management:** Since there is no regenerative braking to recharge the bat- tery, the bike requires an alternative power source, like periodic charging at docking stations or solar charging, if equipped. The power system is carefully managed to en- sure essential functions. (Ref – 11)

4.**Smart Power Management System:** Automatic power Management to battery uses stored regenerative energy to power onboard electronics. Energy efficiency operations ensure minimal energy wastage by prioritizing essential functions.

D. Proposed Work Explanation

1. **Unlocking:** The user unlocks the bike using RFID for contactless, secure access.

2. **Riding:** The bike functions as a regular bike, either with electric assist or manual pedaling, with no regenerative braking to recharge the battery.

3. **Tracking:** GPS tracks the bike’s location in real-time for monitoring and anti-theft purposes. (Ref – 15)

4. **Parking and Locking:** The user ends their session by tapping the RFID tag to lock the bike, logging the trip’s end and switching the bike to a low-power state.

5. **Fleet Management** — Useful for rental operators to monitor bicycle locations and usage patterns.

6. **Battery Monitoring and Maintenance:** Since there is no regenerative braking, the battery is periodically charged externally, while remote diagnostics ensure operational efficiency.

7. **Automatic Power Switching** — Uses stored regenerative energy to power onboard electronics.

8. **Mobile App Control** — Allows users to lock/unlock, track location, and monitor battery status.

9. **Data Analytics** — Provides insights on usage patterns, energy efficiency, and travel history.

10. **Remote Monitoring** — Users can check the status of their bike from anywhere.

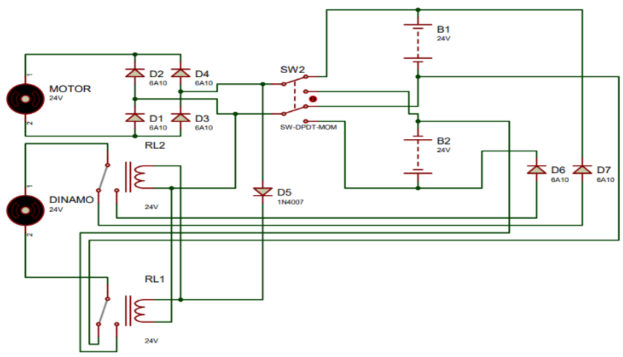

FIG – 2 Circuit diagram for Regenerative cycle with Battery Swapping

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FIG -3 (Testing process of RFID Technology and GPS Tracking)

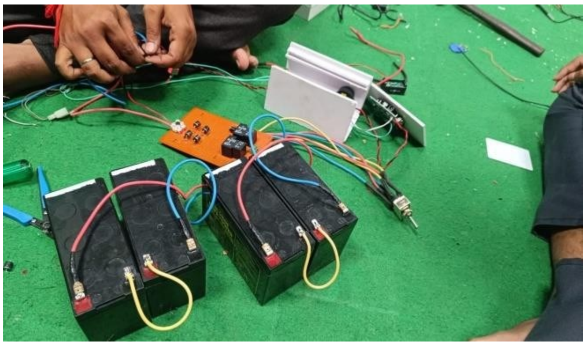

FIG - 4 (Swapping Switch of Batteries Connections)

E. Mathematical Expressions and Symbols

1. Regenerated Power

P generated=T·ω·η

T: Torque applied to the generator.

ω\omega: Angular velocity of the generator (rad/s).

η\eta: Efficiency of the generator.

2. Distance Travelled

Use GPS data to calculate the total distance:

D total= n-1∑i=1√(xi+1−xi)2+(yi+1−yi)2

(xi,yi) (x_i, y_i) (xi,yi): Latitude and longitude of points.

S. NO	COMPONENTS	QUANTITY	RATING	PRICE
1	Lead-Acid Battery	4	12V	6000
2	Wire Harness	-	-	1000
3	Charge Controller	1	10PWM	1500
4	Brush Controller	1	24V,350W	2000
5	Throttle	1	-	500
6	RFID Locking Technology	1	-	4000
7	GPS Tracking	1	-	1500
8	**TOTAL**	9	-	16500

Table – 1 Cost Estimation

Technical Challenges

1. **Energy Harvesting**: Optimizing energy re- generation from braking, pedalling, or other sources while minimizing energy consumption.
2. **Power Management**: Efficiently managing and storing harvested energy, possibly using batteries or supercapacitors**.**
3. **RFID Locking System**: Ensuring secure and reliable locking/unlocking mechanisms using RFID technology.
4. **GPS Tracking**: Integrating GPS modules for accurate location tracking, considering factors like signal strength, battery life, and data transmission.
5. **Efficiency**: Regenerative braking systems on bicycles are less efficient than those in larger vehicles due to limited mass and speed, making energy recovery minima

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6. **Control System:** The system must intelligently decide when to activate regenerative bicycle without affecting the rider's experience.
7. **System Coordination**: Synchronizing RFID, GPS, and regenerative braking requires a robust control system.
8. **Real-time Data Transmission**: Sending GPS data to a cloud or mobile device requires cellular or IoT connectivity, which adds cost and complexity.
9. **Weight and Aesthetics**: Adding multiple electronic components can make the bike heavier and less ergonomic.
10. **Motor and Generator Design** : A hub motor or mid-drive motor must efficiently covert kinetic energy to electrical energy, requiring sophisticated power electronics.

Security Challenges

1. **RFID Hacking**: Protecting the RFID locking system from unauthorized access or hacking attempts.
2. **GPS Spoofing**: Preventing GPS signal manipulation or spoofing, which could compromise location tracking.
3. **Data Encryption**: Ensuring secure data transmission and storage, protecting user information and location data.
4. **Cloud & Mobile App Security Risks:**If the bicycle integrates with a smartphone app, weak authentication mechanisms can lead to unauthorized control.
5. **Tampering & Hardware Attacks :**Attackers could physically disable the RFID reader, GPS tracker, or regenerative bicycle system. Cutting power supply lines could make the security features ineffective.
6. **Denial of Service (DoS) Attacks:** Attackers can flood the GPS system with requests, causes disruptions in tracking or rendering the service unusable.
7. **Battery Theft or Damage**: The bicycle's battery may be targeted for theft or damaged, especially since regenerative braking relies on battery storage.
8. **Bluetooth &Wireless Hacking** :If the bike communicates with a mobile app via Bluetooth or Wi-Fi, attackers could exploit weak encryption. Hackers may remotely unlock or disable the bike.
9. **Theft of Components**: Physical theft of components such as the GPS module or RFID reader can disable the tracking and security systems. If these components are removed or tampered with, the bike may become untrack- able, or the security system may fail.
10. **Power System Vulnerabilities:** At tackers could continuously trigger RFID or GPS functions to deplete battery power. If not properly secured, regenerative bicycle data could be manipulated to alter energy recovery.

V. Results and Discussion

a. **Regenerative Braking**: The bicycle can convert kinetic energy into electrical energy during braking or coasting, allowing the rider to recharge the battery. This is especially useful for powering integrated systems like lights, GPS, and RFID modules.

b. **Extended Range for E-Bikes**: For electric bicycles, regenerative technology increases battery life and reduces the need for frequent charging.

c. **RFID for Authentication**: RFID tags can act as keys, ensuring only authorized users can access or start the bike. This helps prevent theft.

d. **GPS Tracking**: In case of theft, the GPS system allows the owner to locate and re- cover the bicycle quickly. The integration of both technologies enhances security by providing both

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prevention and recovery mechanisms.

FIG - 5 (WORKING ON MOTOR MECHANISMS)

FIG - 5 (CONNECTIONS OF WIRE HARNESS)

Conclusion

In this project model we try to the development of new type of electric vehicles other than normal electric vehicles and hybrid electric vehicles in this model we have using two battery setups first one battery power is to drive the electric vehicles and second battery is to charging form generator. In this bicycle model we get back to power energy approximately 80%-90%.

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