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Retrofitting of Conventional Bike into an E-Bike Using PMSM Motor

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Abstract: *The increasing demand for sustainable and economical transportation has encouraged the development of electric mobility solutions. This project focuses on converting a conventional petrol-powered bike into an selectric bike using a Permanent Magnet Synchronous Motor (PMSM). The existing internal combustion engine is replaced with an electric drive system consisting of a PMSM motor, lithium-ion battery, motor controller, and battery management system. The PMSM motor is selected due to its high efficiency, compact size, smooth operation, and excellent torque characteristics. A Field-Oriented Control (FOC) based controller is used to regulate motor speed and torque effectively. The retrofitted e-bike offers reduced fuel dependency, low maintenance, and environmentally friendly operation. The system also supports regenerative braking to improve energy utilization and battery performance*

Keywords: Electric Bike, PMSM Motor, Retrofitting, Field-Oriented Control (FOC), Battery Management System (BMS), Electric Vehicle (EV), Regenerative Braking, Sustainable Transportation.

I. INTRODUCTION

The rapid growth in population and urban transportation has resulted in increased fuel consumption and environmental pollution. Conventional vehicles powered by internal combustion engines (ICE) release harmful gases such as carbon dioxide, carbon monoxide, and nitrogen oxides, which contribute significantly to global warming and air pollution [1]. Due to the rising cost of fossil fuels and depletion of natural resources, the need for alternative and sustainable transportation systems has become more important in recent years [2].

Electric vehicles (EVs) have emerged as an effective solution for reducing dependence on conventional fuels and minimizing environmental impact. Among different categories of EVs, electric two-wheelers are gaining popularity because of their low operating cost, simple construction, and suitability for urban transportation [3]. However, purchasing a new electric bike can be expensive for many users. Therefore, retrofitting existing petrol bikes into electric bikes provides a practical and economical alternative to achieve sustainable mobility [4].

Retrofitting refers to the process of replacing the internal combustion engine and fuel system of a conventional vehicle with an electric propulsion system. This method allows reuse of the existing vehicle structure while integrating modern electric drive components such as motors, controllers, and battery systems [5]. It reduces material waste, lowers manufacturing requirements, and supports the transition toward green transportation technologies.

In this project, a Permanent Magnet Synchronous Motor (PMSM) is used as the main drive motor for the electric bike. PMSMs are widely used in electric vehicle applications because of their high efficiency, compact size, high torque density, and smooth speed control characteristics [6]. Compared to traditional DC motors and induction motors, PMSMs provide better performance, reduced maintenance, and improved energy efficiency [7].

The retrofitted electric bike system mainly consists of a lithium-ion battery pack, PMSM motor, motor controller, throttle control mechanism, and Battery Management System (BMS). The motor controller uses Field-Oriented Control (FOC) techniques to regulate the motor speed and torque efficiently under different operating conditions [8].

Additionally, regenerative braking is incorporated to recover energy during braking and improve overall battery efficiency [9].

The proposed system aims to provide an eco-friendly, low-maintenance, and cost-effective transportation solution for daily commuting. The project also promotes the concept of reusing conventional vehicles instead of discarding them, thereby reducing environmental waste and supporting sustainable development goals [10].

II. PROBLEM STATEMENT

The increasing use of conventional petrol-powered two-wheelers has led to serious environmental concerns, rising fuel consumption, and higher transportation costs. Emissions from internal combustion engine vehicles contribute significantly to air pollution and global warming, while continuous fuel price increases make daily commuting expensive for common users. Although electric vehicles offer a cleaner alternative, the high cost of purchasing new e-bikes limits their widespread adoption. In addition, disposing of existing conventional bikes results in unnecessary material waste and economic loss. Therefore, there is a need for a cost-effective and sustainable solution that can convert existing petrol bikes into efficient electric vehicles using advanced motor technologies such as Permanent Magnet Synchronous Motors (PMSM), ensuring improved performance, reduced emissions, lower maintenance, and energy-efficient transportation.

III. OBJECTIVES

- To convert a conventional petrol bike into an electric bike using a PMSM motor.
- To design and implement an efficient motor controller for speed and torque control.
- To integrate a lithium-ion battery and Battery Management System (BMS) for safe operation.
- To improve vehicle efficiency and reduce environmental pollution through electric propulsion.
- To evaluate the performance of the retrofitted e-bike in terms of speed, efficiency, and energy consumption.

IV. LITERATURE SURVEY

Kumar et al. (2020) presented a study on retrofitting conventional two-wheelers into electric vehicles by replacing internal combustion engines with electric drive systems. The research highlighted the economic and environmental benefits of retrofitting, including reduced fuel consumption, lower emissions, and reuse of existing vehicle structures. However, the study reported limitations in vehicle efficiency due to the use of low-performance DC motors.

Zhu and Howe (2007) conducted extensive research on Permanent Magnet Synchronous Motors (PMSMs) for electric vehicle applications. Their work demonstrated that PMSMs provide high power density, improved efficiency, compact size, and better thermal performance compared to induction motors. The study concluded that PMSMs are highly suitable for lightweight electric mobility systems, though they require advanced control techniques for stable operation.

Bose (2016) analyzed the performance comparison between PMSM and Brushless DC (BLDC) motors in electric vehicle systems. The research showed that PMSMs offer smoother torque characteristics, precise speed control, and reduced noise levels due to sinusoidal back-EMF generation. However, the implementation cost of PMSM controllers was found to be comparatively higher because of complex control algorithms.

Das and Mandal (2021) developed a Field-Oriented Control (FOC)-based motor controller for PMSM-driven electric vehicles. Their study focused on improving torque response, speed regulation, and regenerative braking efficiency. Experimental results showed enhanced motor performance and energy recovery during braking, although the controller design required precise sensor calibration and computational accuracy.

Hansen et al. (2019) investigated regenerative braking systems in electric bikes and evaluated their impact on battery efficiency and vehicle range. The study confirmed that regenerative braking can recover a portion of kinetic energy during deceleration and improve overall energy utilization. However, the recovered energy was limited during low-speed operation and urban traffic conditions.

Jondra et al. (2023) examined the performance of electric vehicles converted from internal combustion engine vehicles through retrofitting techniques. Their research demonstrated that retrofitted electric bikes achieved lower operational costs, reduced maintenance requirements, and eco-friendly operation.

Comparison Table

Author & Year	Method Used	Advantages	Limitations
Kumar et al. (2020)	Retrofitting conventional bike using electric drive system	Reduced fuel consumption and emissions	Lower motor efficiency
Zhu and Howe (2007)	PMSM motor analysis for EV applications	High efficiency and compact design	Requires complex control
Bose (2016)	Comparison of PMSM and BLDC motors	Smooth torque and better speed control	Higher controller cost
Das and Mandal (2021)	FOC-based PMSM controller design	Improved torque response and regenerative braking	Complex sensor calibration
Hansen et al. (2019)	Regenerative braking system for e-bikes	Better energy recovery and battery efficiency	Limited recovery at low speed
Jondra et al. (2023)	Retrofitting ICE vehicles into EVs	Low maintenance and eco-friendly operation	Battery weight and thermal issues

IV. WORKING OF SYSTEM

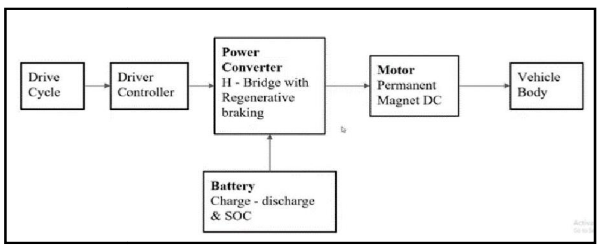

Fig 1: Design of the system

The block diagram represents the working process of the retrofitted electric bike system using a Permanent Magnet DC/PMSM motor. The system converts electrical energy from the battery into mechanical energy to drive the vehicle efficiently.

1. Drive Cycle

The drive cycle acts as the input reference for the system. It represents the speed and acceleration requirements of the rider during different riding conditions such as starting, acceleration, cruising, and braking. This input determines how the vehicle should perform.

2. Driver Controller

The driver controller receives signals from the drive cycle or throttle input and processes them to control the operation of the motor. It generates appropriate control signals for the power converter to regulate motor speed, torque, and direction. The controller ensures smooth acceleration and stable vehicle operation.

3. Power Converter (H-Bridge with Regenerative Braking)

The power converter is the main electronic unit that converts DC power from the battery into controlled electrical power required by the motor. The H-Bridge circuit controls the motor rotation and speed using switching techniques such as Pulse Width Modulation (PWM). During braking, regenerative braking is activated, allowing the motor to operate as a generator and send recovered energy back to the battery.

4. Battery (Charge–Discharge & SOC)

The battery serves as the primary energy source of the system. It supplies DC electrical power to the converter during vehicle operation. The battery also stores recovered energy during regenerative braking. The State of Charge (SOC) monitoring system continuously tracks battery condition, charging level, and power usage to ensure safe and efficient operation.

5. Motor (Permanent Magnet DC/PMSM Motor)

The motor converts electrical energy into mechanical rotational energy. When power is supplied from the converter, the motor rotates and generates torque to drive the wheels of the bike. The PMSM motor provides high efficiency, smooth operation, low noise, and better torque characteristics for improved vehicle performance.

6. Vehicle Body

The vehicle body represents the mechanical structure of the bike, including wheels, frame, and transmission system. The rotational motion produced by the motor is transferred to the wheels, which propels the bike forward. During braking or deceleration, part of the kinetic energy is recovered through regenerative braking and stored back in the battery.

Overall, the system ensures efficient energy conversion, smooth speed control, reduced emissions, and improved performance for sustainable electric transportation.

V. SYSTEM DESIGN

1. System Overview

The proposed system is designed to convert a conventional petrol-powered bike into an electric bike using a Permanent Magnet Synchronous Motor (PMSM). The system mainly consists of a lithium-ion battery pack, motor controller, PMSM motor, throttle control, Battery Management System (BMS), regenerative braking unit, and high-voltage wiring system. The battery supplies DC power to the controller, which converts it into three-phase AC power required for the PMSM motor. The motor then drives the rear wheel through a chain drive mechanism. The controller continuously regulates speed and torque based on throttle input while ensuring efficient energy utilization and safe operation.

1.1 Drive Cycle

The drive cycle provides the reference speed and acceleration conditions of the vehicle. It represents the riding conditions such as starting, acceleration, cruising, and braking. The controller uses this input to regulate the performance of the electric bike.

1.2 Driver Controller

The driver controller acts as the main control unit of the system. It receives throttle input from the rider and generates control signals for the power converter. It ensures smooth acceleration, speed regulation, and efficient motor operation using FOC techniques.

1.3 Power Converter (H-Bridge with Regenerative Braking)

The power converter converts DC power from the battery into controlled three-phase AC power for the PMSM motor. It also controls motor direction and speed using PWM switching techniques. During braking, regenerative braking converts kinetic energy into electrical energy and stores it back into the battery.

1.4 Battery Pack

The lithium-ion battery pack serves as the main energy source of the system. It supplies electrical power to the motor controller and stores regenerated energy during braking. The battery provides high energy density, lightweight operation, and long cycle life.

1.5 Battery Management System (BMS)

The BMS continuously monitors battery voltage, current, temperature, and state of charge (SOC). It protects the battery from overcharging, over-discharging, overheating, and short circuits to ensure safe operation.

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1.6 PMSM Motor

The Permanent Magnet Synchronous Motor converts electrical energy into mechanical rotational energy. It provides high torque, high efficiency, smooth operation, and low maintenance, making it suitable for electric vehicle applications.

1.7 Vehicle Body

The vehicle body includes the frame, wheel assembly, chain drive, and braking system. The mechanical output of the PMSM motor is transferred to the rear wheel to propel the vehicle.

2. Component Description

2.1 PMSM Motor

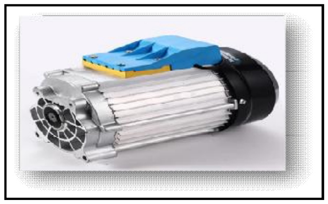

Fig.2.PMSM Motor

The PMSM motor is the primary driving component of the electric bike. It operates using permanent magnets mounted on the rotor and three-phase windings on the stator. The motor offers high efficiency, compact size, low noise, and excellent torque characteristics.

Specifications:

Rated Power: 2 kW
Rated Voltage: 60 V
Speed: 3000 RPM
Efficiency: 90–95%
Peak Torque: 33 Nm
Cooling Type: Air Cooled

2.2 Motor Controller

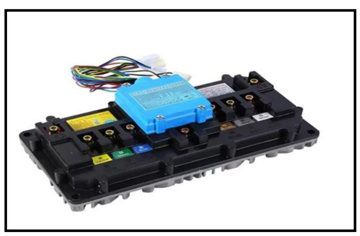

Fig.3.Motor Controller

The motor controller regulates the speed and torque of the PMSM motor using Field-Oriented Control (FOC). It converts DC battery power into controlled AC supply and ensures smooth motor operation.

Features:

PWM-based switching
Regenerative braking
Overcurrent protection
Overvoltage protection
Temperature protection

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2.3 Battery Pack

The lithium-ion battery stores electrical energy required to operate the electric bike. It supplies stable DC power to the controller and supports long-duration operation.

Features:

High energy density
Fast charging capability
Long battery life
Lightweight design

2.4 High Voltage Wiring System

The high-voltage wiring system transfers electrical power between the battery, controller, and motor. It includes insulated cables, fuses, connectors, and contactors for safe operation.

Safety Features:

Insulated connectors
Fuse protection
Grounding system
EMI shielding
High Voltage Interlock Loop (HVIL)

2.5 Motor Design

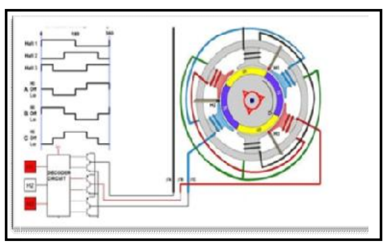

Fig.4.Motor Design

The motor design of the retrofitted e-bike is based on a Permanent Magnet Synchronous Motor (PMSM), selected for its high efficiency, compact size, and superior torque performance. The design focuses on achieving reliable operation, smooth speed control, and efficient power conversion suitable for electric vehicle applications.

2.6 Circuit Diagram

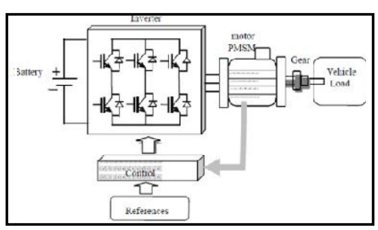

Fig.5.Circuit Diagram

The circuit diagram of the retrofitted electric bike represents the electrical connections between the battery pack, motor controller, PMSM motor, throttle, BMS, and protection devices.

VI. RESULTS

The retrofitted electric bike using a Permanent Magnet Synchronous Motor (PMSM) was successfully developed and tested under different operating conditions. The system demonstrated smooth acceleration, stable speed control, and efficient power delivery through the Field-Oriented Control (FOC)-based motor controller. The PMSM motor provided high torque at low speeds, resulting in improved vehicle pickup and better riding performance compared to conventional drive systems. The lithium-ion battery pack supplied reliable power to the motor, while the Battery Management System (BMS) ensured safe charging and discharging operation throughout the testing process.

Experimental evaluation showed that the retrofitted e-bike achieved a maximum speed of approximately 60 km/h with efficient energy utilization and reduced operational noise. The regenerative braking system successfully recovered a portion of kinetic energy during braking, improving the overall battery efficiency and vehicle range. The motor operated with an efficiency of nearly 90–95%, while the controller maintained stable operation under varying load conditions. The system also produced significantly lower emissions and reduced maintenance requirements compared to conventional petrol-powered bikes.

Overall, the project confirmed that retrofitting a conventional bike into an electric bike using a PMSM motor is a practical, economical, and environmentally sustainable solution for modern transportation.

VII. CONCLUSION

The project “Retrofitting of Conventional Bike into an E-Bike Using PMSM Motor” successfully demonstrated the conversion of a conventional petrol-powered bike into an efficient electric vehicle. The integration of the Permanent Magnet Synchronous Motor (PMSM), lithium-ion battery pack, and Field-Oriented Control (FOC)-based controller provided smooth speed regulation, high torque performance, and efficient energy utilization. The developed system achieved reliable operation with reduced noise, low maintenance, and improved overall efficiency compared to conventional internal combustion engine vehicles. The regenerative braking feature further enhanced battery performance by recovering energy during braking conditions. The project also highlighted the environmental and economic benefits of retrofitting, including reduced fuel consumption, lower emissions, and reuse of existing vehicle structures. Overall, the proposed system offers a sustainable, eco-friendly, and cost-effective solution for electric mobility and supports the growing demand for clean transportation technologies.

VIII. FUTURE SCOPE

The future scope of the project includes the integration of advanced Battery Management Systems (BMS) with IoT-based monitoring for real-time battery analysis and performance tracking. The regenerative braking system can be further improved to increase energy recovery efficiency and extend vehicle range. Future developments may also include AI-based motor control techniques for adaptive speed and torque management under varying road conditions. The use of lightweight materials and advanced magnetic components can further improve motor efficiency and reduce overall vehicle weight. Solar-assisted charging systems and fast-charging technologies can also be incorporated to make the e-bike more energy-efficient and user-friendly. Additionally, the retrofitting concept can be expanded for commercial vehicles, delivery bikes, and public transportation systems to support large-scale adoption of sustainable electric mobility.

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