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Electric Bicycle using Pedal Assist System (PAS)

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***Abstract*—The purpose of this paper was to design and build an electric bicycle that incorporates the Pedal Assist System (PAS). The PAS system detects when the rider starts pedaling and immediately kicks in to provide electric assistance, making riding easier and more efficient. Our team utilized a lithium-ion battery and a brush less DC motor to power the PAS system. The bicycle was designed to be easy to ride, energy efficient and sustainable mode of transportation. The PAS system was successfully integrated into the bicycle, and it proved to be highly effective in assisting the rider. Overall, our paper successfully demonstrated that PAS based electric bicycles are a viable alternative to traditional bicycles and gasoline- powered vehicles, with the potential to revolutionize personal transportation.**

Keywords—Pedal Assist System (PAS), electric bicycle, brushless DC motor, energy efficient.

I. INTRODUCTION

PAS (Pedal Assist System) based e-bicycles are an innovative and eco-friendly mode of transportation that combine the best of traditional bicycles with electric motor technology. PAS e-bicycles utilize a small electric motor that is integrated into the frame of the bicycle, which assists the rider when pedaling. The Pedal Assist System uses sensors to detect when the rider is pedaling and then provides a boost to the pedaling effort, resulting in a smoother, more efficient ride. PAS e-bicycles typically have several levels of assistance, allowing the rider to choose the level of electric motor assistance that best suits their needs. E-bikes with PAS support the concept of sustainable transport and have been identified as a promising solution to reducing carbon emissions and improving physical activity levels. A pedal assist system, also, is a feature commonly found in electric bicycles (e-bikes). It is designed to augment the rider's pedaling power with an electric motor, providing a smoother and more natural riding experience. Here's how a typical pedal assist system works.

A. *Benefits of Pedal Assist Systems:*

- Extended Range: Pedal assist systems help riders cover longer distances without getting fatigued.
- Fitness Support: Riders can choose the level of assistance, allowing them to get exercise while still receiving help when needed.
- Eco-Friendly: E-bikes with pedal assist systems are an environmentally friendly transportation option, as they reduce reliance on traditional gas-powered vehicles.

Overall, pedal assist systems enhance the overall riding experience of electric bicycles, making them a popular choice for commuting, recreational riding, and fitness. In summary, electric bicycles with Pedal-Assist Systems (PAS) have revolutionized the way we perceive and experience cycling. They combine the convenience of an electric motor with the physical activity of pedaling, resulting in a harmonious blend that enhances performance, versatility, and sustainability. With their growing popularity and numerous benefits, PAS e-bikes are poised to shape the future of urban mobility and redefine our approach to personal transportation

II. ADVANTAGE AND APPLICATION

A. *advantages*

Pedal assist systems enhance the cycling experience by combining the benefits of traditional cycling with the advantages of electric assistance. They provide riders with increased range, improved efficiency, flexibility and control, Uphill assistance and a more enjoyable riding experience while promoting physical activity and sustainable transportation.

B. *Applications*

- Bike Sharing Programs
- Delivery Services
- Touring and Adventure Cycling
- Outdoor Recreation
- Commuting and Urban Mobility
- Rehabilitation and Mobility Assistance
- Personal Fitness and Exercise

III. PROPOSED BLOCK DIGRAM

A. *Block Diagram*

Pedal Assist - The mid-drive electric bike consists of a 250W BLDC shaft motor. This motor is mounted above the crank of the bicycle which is powered by a 36V, 12Ah Li-ion battery. This motor is controlled by a BLDC driver.

BLDC driver input is given by the throttle during throttle mode

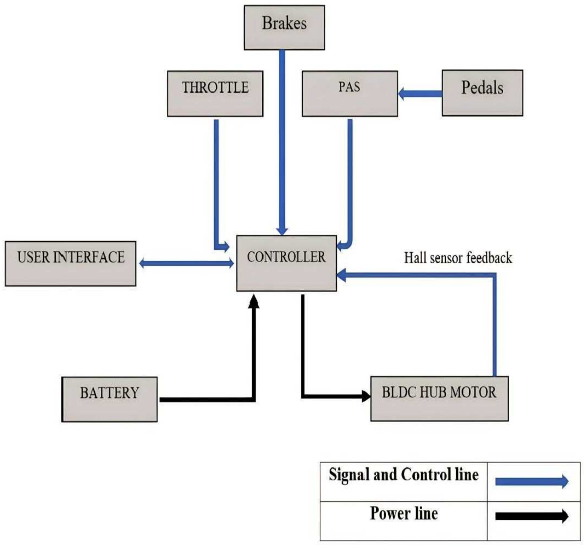

Fig. 1. Proposed Block Diagram of Electric Bicycle using PAS

B. Description

- Pedal Assist - The mid-drive electric bike consists of a 250W BLDC shaft motor. This motor is mounted above the crank of the bicycle which is powered by a 36V, 12Ah Li- ion battery. This motor is controlled by a BLDC driver. BLDC driver input is given bythe throttle during throttle mode.
- In Pedal Assistant mode, the cyclist can select different assistance modes via the LCD console according to their needs. From the motor, a chain drive is connected to the bicycle crank.
- A freewheel is mounted between the crank and the axle of the bike to prevent the pedals from turning when the motor is on.
- The Orbitrack speed sensor is used to detect pedal rotation. Based on the Orbitrack speed sensor output micro controller, it will provide power to the BLDC motor. This Mid-Drive electric bicycle can also be used as a normal bicycle.
- The BLDC hub motor is included into the e-bicycle through hall sensor feedback. Through the use of the signal line, control line, and power line controls, the user interface offers the ability to manage the throttle and PAS.
- The BLDC motor determines the sensor's location and feeds the controller the sensor's output. The controller receives the variable voltage from the throttle and uses the battery that is linked to the controller to drive the motor in accordance with the variable voltage. By powering the motor, the pedal assist sensor (PAS) assists the user in pedaling

IV. MATHEMATICAL MODELIING

A. BLDC Motor Modeling

Power rating of BLDC motor to design E-bicycle of 15kg with a max speed of 25km/hr.

F(Total)=F(rolling) + F(gradient) + F (Aerodynamic drag) (1)

F (rolling) = Cr* M* A (2)

= 0.008(rough road) * 90* 9.81

= 7.06 Newton (N)

Where, Cr = Coefficient of rolling resistance

M = Total mass in kg= 15+75= 90 Kg

A = Acceleration due to gravity 9.81 m/s^2

Power required to overcome rolling resistance= F(rolling)*Velocity of bicycle in m/s^2 (3)

= 7.06* 6.94

= 49 Watt

Gradient resistance= Mass* Sin (θ) (4)

Consider Angle (θ) = 0 as vehicle is travelling on flat surface.

F (gradient) = 0 N. (108.4 W)

F (Aerodynamic drag) = 0.5* δ* V^2 * C_a* A_f

Where,

δ = Density of air medium= 1.23 kg/m^3 (for air at sea level)

V= Velocity of bicycle= 6.94 m/s

C_a= Coefficient of air resistance (At upright position)

= 0.8 A_f

= Frontal area of bicycle at upright position

= 0.51 m^2

Power required to overcome air resistance= Aerodynamic drag (12.1) * Velocity (6.94) = 84 Watt

Therefore, total power required to overcome these resistance forces is equal to the power required to move the bicycle.

Power rating of motor = 49+ 0+ 84= 133 Watt (5)

B. Battery Pack

TABLE I. BATTERY PACK PARAMETERS

Sr. No	***Particulars***	***Rating***
1	Voltage rating of each cell	3.2 V
2	Current rating of cell	6000 mAh
3	IS 16046 standards	Prevention from Hazards (Fire, Explosion, Leakage proof)
4	Efficiency	Upto 85%
5	Controllability	Hall Sensor

From the above table,

Voltage rating of battery pack: - 3.2 * 12= 38.4 V
Current rating of battery pack: - 6000* 2= 12 Ah
Energy Density of battery pack: - 12 * 38.4= 460.8 Wh

If we are using BLDC motor having a rating of 250W and considering speed of 25 km/hr.

Time required for discharge of battery pack: 460.8/250= 1.84= 1hr & 50 minutes Range of bicycle at 25 km/hr for 1hr & 50 minutes= 46 km (6)

V. DETAILS OF HARDWARE

A. 36 V BLDC Hub motor

TABLE II. DETAILS OF BLDC MOTOR

Sr. No	*Particulars*	*Rating*
1	BLDC motor	36 V, 250W
2	IP Rating	IP65(Protection from dust, dirt and low-pressure water sprays)
3	Standard	NEMA 23
4	Efficiency	Up to 85%
5	Controllability	Hall Sensor

Fig. 2. BLDC hub motor

B. CADENCE Sensor

The CADENCE sensor consists of a small magnet attached to the crank arm or pedal and a sensor mounted on the bicycle frame. As the rider pedals, the magnet passesby the sensor, creating a signal that is sent to the e-bike's motor controller By incorporating a CADENCE sensor into the PAS, e-bike manufacturers can offer a more intuitive and responsive riding experience. The motor assistance can be synchronized with the rider's pedaling cadence, providing a natural and seamless boost as needed. This helps optimize the efficiency of the electric motor and allows riders tobetter control their riding speed and effort.

Fig. 3. CADENCE Sensor

Fig. 4. CADENCE Sensor Location

C. Throttle

Fig. 5. Throttle-I

When the rider activates the throttle, it sends a signal to the motor controller, instructing it to deliver power to the electric motor. The amount of power applied depends on how much the rider twists or pushes the throttle

Fig. 6. Throttle-II

D. Battery

Lithium-ion phosphate ($LiFePO_4$), also known as lithium-Ion battery or LFP battery, is a type of lithium-ion battery commonly used in e-bicycles and other electric vehicles. It offers several advantages over other types of lithium-ion batteries, such as lithium cobalt oxide ($LiCoO_2$) or lithium manganese oxide ($LiMn_2O_4$). It offers several advantages over other types of lithium-ion batteries, such as lithium cobalt oxide ($LiCoO_2$) or lithium manganese oxide ($LiMn_2O_4$). Here are some key characteristics of lithium-Ion batteries

Fig. 7. Battery cell FB Tech Lithium-Iron Phosphate ($LiFePO_4$) rechargeable cells (49 gram)

E. Battery Pack

Designing a battery pack involves several considerations, and the specifics depend on the application, the type of batteries used, and the desired performance.

Fig. 8. Battery Pack

TABLE III. BATTERY PACK PARAMETERS

Sr. No	***Particulars***	***Rating***
1	Li-Ion Battery Pack	35.2V, 12 Ah
2	Safety	Prevention from Hazards (Fire, Explosion, Leakage proof).
3	Cell Design	Series Combination of 11 cells which forms 1 row & 2 Such Rows which areconnected in parallel give us a rating

F. Motor Controller

TABLE IV. DETAILS OF MOTOR CONTROLLER

Sr. No	***Particulars***	***Rating***
1	Specification	36V, 12 A, 300 W
2	Rated voltage	DC 36 V
3	Rated Power	300 W
4	Motor Speed	0 to approximately 25km/h variable-speed by handle bar

The most widely used method of speed control for electrical motors is PWM. This method works by multiplying an inverter's switching signals by a high frequency signal with a particular duty cycle. Using this method, PWM pulses for a three-phase inverter bridge are generated by comparing the duty cycle and back EMF waveforms.

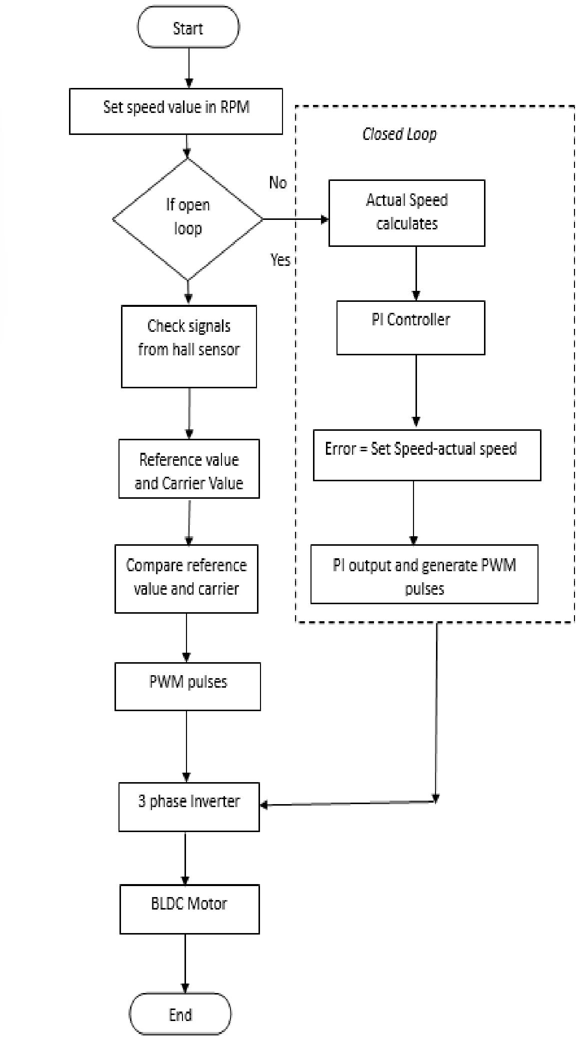

Fig. 9. Flowchart of Motor speed control using PWM Technique

Fig. 10. Electric Bicycle using PAS

VI. Testing and Observation

TABLE V. TABLE TYPE STYLES

Sr. No.	Testing and Observation	
	Parameters	***Observation***
1	Driving experience	Easy to use and healthy for life
2	Maximum speed obtained	25Km/hr
3	Average speed obtained	20-22 Km/hr
4	Working of the controller	Easily Controllable
5	Charging time for battery	Min 3hr

Conclusion

Electric bicycle pedal assist systems enhance the cycling experience by combining the benefits of traditional cycling with the advantages of electric assistance, making cycling more accessible, enjoyable, and sustainable for a broader range of individuals offer an eco-friendly alternative for commuting and recreational purposes, promoting cleaner air and reducing traffic congestion.

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