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An Electrical Rotating Device Assisted Electric Bicycle with Advanced Battery Technology

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Abstract: ***An electrical rotating device assisted electric bicycle, derived from a regular battery operated electric bicycle having a redesigned frame with a paddling axis shifted towards the front wheel and by providing a conversion equipment comprising the electrical rotating device acting as a motor and a generator; a direct current (DC) to pulse width modulating alternating current (AC) converter, the DC to pulse width modulating AC converter feeding pulse with modulated (PWM) AC supply to the electrical rotating device when acting as a motor; a Hall effect speed controlling device mounted on a handle of the electric bicycle; a battery chamber containing a plurality of 12V, 36V and 48V re-chargeable batteries; a three phase rectifier; and a head panel for display and controls disposed on a handle bar of the electric bicycle, the electrical rotating device assisted electric bicycle has at least a Power mode, a Charge mode and a Manual mode.***

Keywords: ***Electric Bicycle, Hall Effect, Paddling Axis, Rotating Device***

I. INTRODUCTION

Traditional bicycle is an economical, light weight and eco-friendly mode of transport for short distances. With the technological advancements and miniaturization in products like motors, batteries and electronics there are attempts to build in some amount of automation in traditional bicycles. The bicycle being a travelling aid for short distances and for users who need relatively simple, economical and maintenance free product. There is a need to have an optimally designed electric bicycle. The electric bicycle is developed from a conventional bicycle by additionally providing conversion equipment comprising the electrical rotating device which acts as a motor and also as a generator, direct current (DC) to pulse width modulating alternating current (AC) converter, a Hall effect speed controlling device (Sensor), a battery chamber containing a plurality of re-chargeable batteries and a series and parallel combination of various cells, a three phase rectifier and a head panel for display and controls. The electric bicycle is created by accommodating conversion equipment on the conventional bicycle with a redesigned frame having a paddling axis shifted towards the front wheel in order to create some room near the rear wheel.

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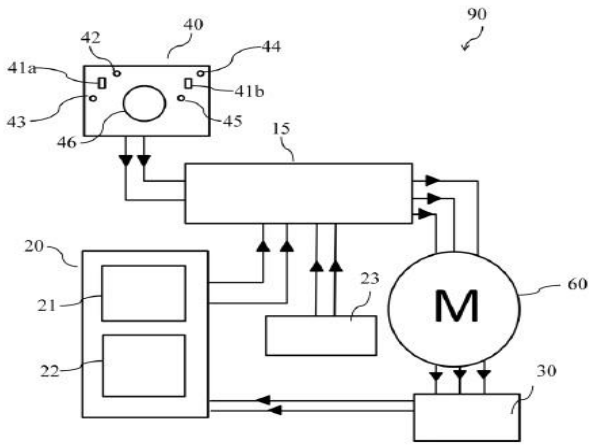
Notably, the battery chamber has multiple light weight re-chargeable batteries, connectable in series or parallel as described below. As a further advantage, due to providing multiple batteries, 4 the batteries are accommodated in a slender rectangular volume, created between a rear wheel and a seat support of the redesigned frame. The electrical rotating device deployed is a commutator-free, brushless series motor with inverse torque speed characteristics. The electrical rotating device is designed with a relatively large diameter and a small length. Due to the small length, which is less than one third of the diameter, the electrical rotating device is rotatable mounted on an already present hub of the rear wheel of the electric bicycle so that the electrical rotating device drives the electric bicycle without needing any connecting gears or any additional part. The DC to pulse width modulating AC converter is deployed to feed pulse with modulated (PWM) AC supply to the electrical rotating device when running as the motor. The Hall Effect speed controlling device comprises a first permanent magnet, a second permanent magnet and a Hall Effect sensor. The first permanent magnet is non movably disposed while the second permanent magnet is disposed movably along the periphery of a circular ring. The Hall Effect sensor is disposed in between the first permanent magnet and the second permanent magnet. The Hall Effect speed controlling device is deployed in the present invention to produce a variable Hall voltage VH which is fed to the converter in order to run the bicycle at different speeds. The Hall Effect speed controlling device is disposed in a handle of the electric bicycle. The head panel for display and controls comprises a selector switch S1, a selector switch S2, indicating lamps, a display panel and a head lamp. The head panel for display and controls is disposed on a handle bar of the electric bicycle. The electric bicycle as per present invention has at least three modes- a Power mode, a Charge mode and a Manual mode. In the Power mode, the electrical rotating device acts as the motor and the two 12V lightweight batteries get connected in series so as to create a 24V DC source which is an input to the DC to AC converter. In the Charge mode, the electrical rotating device acts as the generator and the electrical rotating device produces three phase pulsating waves of voltage when a rotor of the electrical rotating device is made to rotate either by paddling or by any other mechanical means. Through the three phase rectifier, the pulsating voltage is converted to DC for charging the 5 batteries. Through another switch S2 on the head panel, the user can select and charge the individual 12V battery one by one. A voltage booster circuit when used, facilitates charging all the batteries simultaneously. In the Manual mode, the electric bicycle runs as a normal bicycle.

II. EVALUATION OF THE STATE-OF-THE-ART

In the Electric vehicle mathematical model is studied and control strategies is analysed with calculation of system reliability is introduced [1]. Electric Bicycle play important role in U.S. market. Many systematic, comprehensive, theoretically and experimentally based reports give information about need and challenges in designing electric bicycles with improved overall performance [2]. Regenerative power control for electric bicycle uses PM brushless dc motor. Regenerative power control circuit is absorbing regenerative power in the battery. Details of the motor and the electronic converter are given. The regenerative power control for electric bicycle method is a sample and a low-cost solution [3]. An electric bicycle based on a blushless dc motor drive which has high efficiency, zero pollution, clean and convenient, is then designed and implemented. The hardware and software design based on a microcontroller is analyzed. The experimental results show the feasibility and fidelity of the complete designed system [4]. In electric bicycle a rear wheel BLDC hub motor,lead acid battery pack, a light weight chassis, a controller is used. But there is limitation of life span and performance of battery. So super-capacitor modules are recent research area in Electric bicycle which provide the high current required during starting and acceleration and A secondary source, like regenerative braking or a small solar panel module could be availed onboard so as to charge battery/ super capacitor [5]. An electronic module introduce low power, 8-bit microcontroller can be used to drive such a motor and also manage other useful functions on an e-Bike [6]. E-bike comprises the features like high mobility efficiency, compact, electrically powered, comfortable riding experience, light weight vehicle. E-bike is the most versatile future vehicle considering its advantages [7]. The increased use of non-renewable fossil fuels brings with it environmental problems such as: the "greenhouse effect", health problems for city delivers and concern over the stability of fuel supply. To move away from this dependence on oil, a vast amount of money is being spent on the development of electrical vehicles (EVs) that may be produced. The electric vehicle implemented by removing the internal combustion engine, the exhaust system and other unnecessary components from the motorcycle and replaced by an electrical motor, an intelligent controller, and a battery pack, cabling system and monitoring instruments [8]. Electric bike which will be driven with the help of battery and thus provide required voltage to the motor. The focus of this report is to perform power calculations and system design of Electric Bike. Electric bike can be driven with the help of electricity or also with the help of solar energy. Therefore the manufacturing of such bike is indispensable [9]. E-bike comprises the features like high mobility efficiency, compact, electrically powered, comfortable riding experience, and light weight vehicle. E-bike is the most versatile future vehicle considering its advantages. From the consumer's point of view, only the costs paid from purchase until retirement are included in the cost of EBs, i.e., the EB acquisition cost, battery replacement cost, charging cost, and repair and maintenance cost are included [10]. Considered from the perspective of the social cost (including impact on the environment), costs that are not paid directly by consumers should also be included in the cost of EBs, i.e., the lead-acid battery scrap processing cost, the cost of pollution caused by wastewater, and the traffic-related costs [11]. Electric bikes we use electrical motor (BLDC motor) instead of combustion engine as there is less pollution, low maintenance cost, reduces noise [12]. These bikes utilize chemical energy stored in the rechargeable battery packs [13]. There is a distribution for charging the battery emitting it from the main system [14]. The developed system is constituted in a first approach by two different power sources: one is constituted by batteries or by fuel cells, and the other by supercapacitors [15]. A technical solution joining and accomplishing the usage of two energy storage systems in the same traction system [16]. In the developed system, the supercapacitors run as element that store energy temporarily and that can be used to retrieve energy [17]. Starting from the functional characteristics of typical electrical vehicles and characterization of a typical routing profile, the energy consumption is obtained [18].

III. RESEARCH METHOD

The invention shall now be described with the help of accompanying drawings. It is to be expressly understood that several variations of the concept of present invention are possible and the description should not be construed to limit the invention in any manner whatsoever. Our invention is an electrical rotating device assisted electric bicycle. The electric bicycle is developed from a conventional bicycle by additionally providing a conversion equipment (90), as shown in Figure 1:

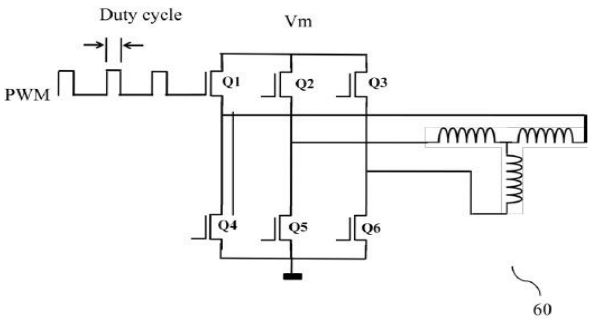


[Fig.1: (A) Block Diagram of Conversion Equipment for an Electric Bicycle]

- An electrical rotating device (60) which acts as a motor and also as a generator,
- A direct current (DC) to pulse width modulating alternating current (AC) converter (15),
- A Hall Effect speed controlling device (23),
- A battery chamber (20) containing a plurality of 12V re-chargeable batteries (21, 22),
- A three phase rectifier (30),
- An optional voltage booster (50) and
- A head panel (40) for display and controls.

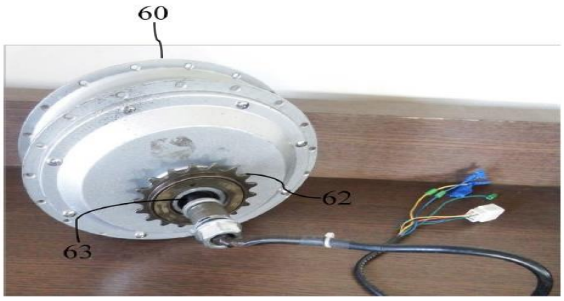
[Fig.1: (B) Picture of an Embodiment of the Electric Bicycle]

Figure 1A, the electric bicycle (100) is created by accommodating conversion equipment (90) on the conventional bicycle with a redesigned frame (95). The redesigned frame (95) has a paddling axis (3) shifted towards a front wheel (1) in order to create some room near a rear wheel (2). Notably, the battery chamber (20) has a plurality of light weight re-chargeable batteries like lithium-ion batteries. The present embodiment is described with two 12V lightweight batteries (21 and 22), however the invention can be worked with more number of light weight batteries of different voltage. Due to a plurality of batteries (21, 22, …), the batteries (21, 22) are accommodated in a slender rectangular volume, created between the rear wheel (2) and a seat support of the redesigned frame (95). It is known that reduction in size, weight and increase in charge carrying capacity of batteries has been revolutionizing products and present invention further increases the benefit by providing a plurality of light weight batteries instead of a single large battery as described further below.7



[Fig.2: (A) Schematic of an Electrical Rotating Device and Pulse Width Modulated Wave]

Figure 2, the electrical rotating device (60) deployed is a commutator-free,brushless series motor with inverse torque speed characteristics, which also runs as a generator. The electrical rotating device (60) has a plurality of rotating magnets on a rotor while an armature is wound like in three phase configuration. As is known, while a direct current is fed to a DC series motor, a commutator converts the direct current into a pulsating current of changing direction, for a motor to run as per famous Fleming's left hand rule. In commutator free brushless motors, such conversion from direct current to changing direction pulsating current is done by the aid of an electronic circuit, in place of the commutator. Such motors are free from fire hazard owing to absence of sparks which otherwise are generated on segments of commutator.



[Fig.2: (B) Picture of an Embodiment of an Electrical Rotating Device]

Figure 2B, the electrical rotating device (60) is designed with a relatively large diameter and small length to exploit the known equation:

$P = KD^2 L$

Where

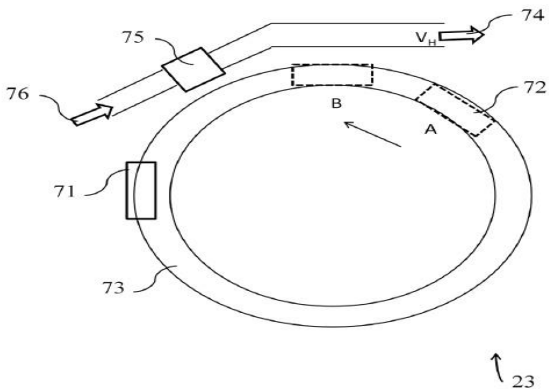
P = Power consumed/generated

D = armature diameter

L = length of armature winding

k = a constant

Electrical rotating devices with large diameters are particularly suitable for low rotational speeds since more number of permanent magnet poles can be accommodated and the centrifugal force on windings is limited due to lower speed. Due to a small length L, which is less than one third of a diameter D, the electrical rotating device (60) is rotatable mounted on an already present hub of the rear wheel (2) of the electric bicycle (100) so that the electrical rotating device (60) drives the electric bicycle (100) without needing any connecting gears or any additional part. 8 The DC to pulse width modulating AC converter (15) is deployed to feed pulse with modulated (PWM) AC supply to the electrical rotating device (60) when running as the motor. The voltage booster (50) is deployed optionally after the three phase rectifier (30).



[Fig.3: Concept Diagram of a Hall Effect Speed Controlling Device]

Figure 3, a Hall Effect speed controlling device (23) comprises a first permanent magnet (71), a second permanent magnet (72) and a Hall Effect sensor (75) along with associated operational circuit.

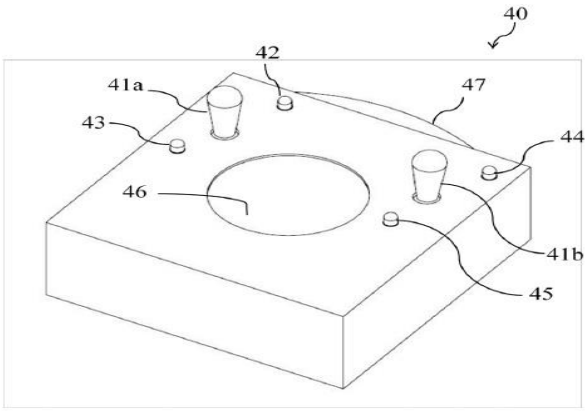
The first permanent magnet (71) and the second permanent

magnet (72) are disposed around a periphery of a circular ring (73). The first permanent magnet (71) is non-movably disposed while the second permanent magnet (72) is disposed movably along the periphery of the circular ring (73). The Hall Effect sensor (75) is disposed in between the first permanent magnet (71) and the second permanent magnet (72). As is known, when the Hall Effect sensor (75) carries a prescribed current in a direction and is in a magnetic field in an orthogonal direction then the Hall Effect sensor (75) produces a Hall voltage VH (74) which is proportional to an intensity of the magnetic field. The Hall Effect speed controlling device (23) is deployed in the present invention to produce a variable Hall voltage VH (74) which is fed to the DC to AC converter (15) in order to run the electric bicycle (100) at different speeds as described below.

[Fig.3: (A) Pictures of an Embodiment of a Handle Housing the Hall Effect Speed Controlling Device of the Electric Bicycle]

[Fig.3: (B) Pictures of an Embodiment of a Handle Housing the Hall Effect Speed Controlling Device of the Electric Bicycle]

Figures 3A and 3B, the Hall Effect speed controlling device (23) is disposed in a handle (80) of the electric bicycle (100) such that when a user rotates the handle (80) from an initial situation (81) towards an accelerating situation (82), the second permanent magnet (72) rotates, illustratively from a position A to a position B as shown in Figure 3.

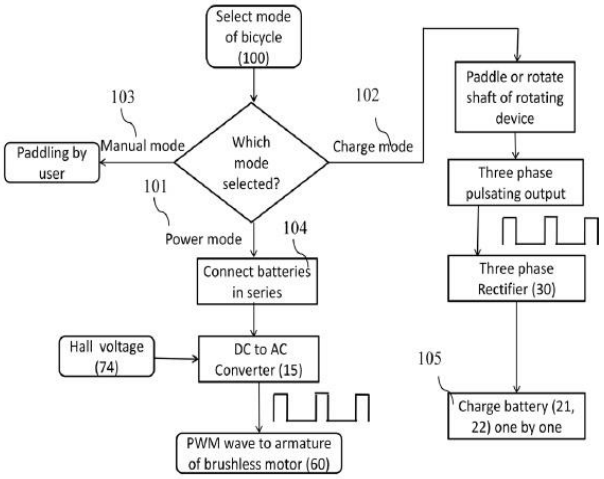


[Fig.4: (A) Representative Diagram of a Head Panel for Display and Controls]

Figure 4, the head panel (40) for display and controls comprises a selector switch S1 (41a), a selector switch S2 (41b), indicating lamps (42, 43, 44 and 45), a display panel (46) and a head lamp (47).

[Fig.4: (B) A Picture of an Embodiment of the Head Panel for Display and Controls]

The head panel (40) for display and controls is aesthetically designed as shown in Figure 4A as one embodiment and disposed on a handle bar (6) of the electric bicycle (100).



[Fig.5: (A) Flow Diagram of Functioning of the Electric Bicycle in Different Modes]

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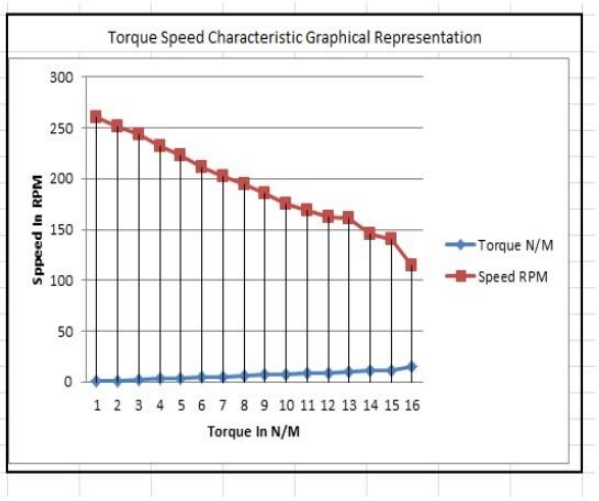
Figure 5, the electric bicycle (100) as per present invention has at least three modes: 9

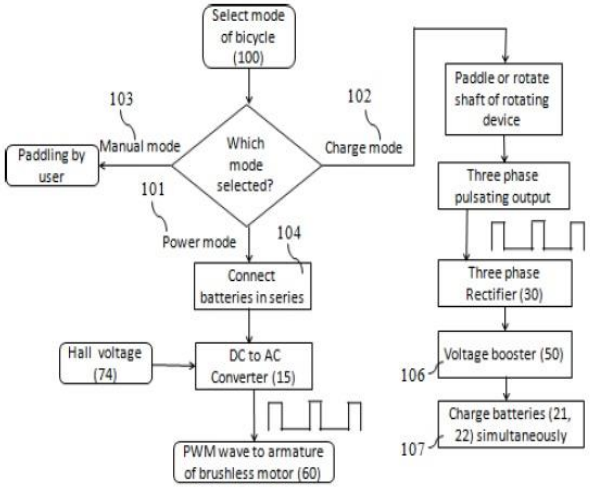
1. Power mode (101)
2. Charge mode (102)
3. Manual mode (103)

In the Power mode (101), the electrical rotating device (60) acts as the motor and drives the rear wheel (2) when the selector switch S1 (41a) on the head panel (40) is turned to the Power mode (101) and the indicating lamp (43) starts glowing. Electric power to the electrical rotating device (60) is supplied from the DC to AC converter (15) in the form of pulse width modulated square waves. By rotating the handle (80), the Hall voltage VH (74) is varied which in turn varies a pulse width of the square wave and the electrical rotating device (60) rotates with different speed and corresponding torque as per a torque speed graph in Figure 2A.



[Fig.5: (B) A Torque-Speed Diagram of the Electrical Rotating Device]

In the Power mode (101), the two 12V lightweight batteries get connected in series (104) so as to create a 24V DC source which is an input to the DC to AC converter (15). In the Charge mode (102), the electrical rotating device (60) acts as a generator when the selector switch S1 (41a) on the head panel (40) is turned to the Charge mode (102) and the indicating lamp (45) starts glowing. In this state, the electrical rotating device (60) produces three phase pulsating waves of voltage when the rotor of the electrical rotating device (60) is made to rotate either by paddling or by any other mechanical means. Through the three phase rectifier (30), the pulsating voltage is converted to DC for charging the batteries (21, 22). Through another selector switch S2 (41b) on the head panel (40), the user can select and charge the individual 12V battery (21 or 22) one by one (105). An indicating lamp (42 or 44) on the head panel (40), corresponding to each of the 12V battery glows when the corresponding battery (21 or 22) is charged. Since the batteries (21, 22) are charged one by one, even slow paddling does proper charging of batteries (21, 22). In the Manual mode (103), the electric bicycle (100) runs as a normal bicycle. In any of the modes, the display panel (46) on the head panel (40) for display and controls shows the speed of the electric bicycle (100), the state of head lamp (47) , the state of charge of the batteries (21, 22,…), the health of the DC to AC converter (15). When more 10 than two batteries (21, 22,…) are provided, they are all connected in series in the Power mode (101) and are charged one by one in the Charge mode (102).



[Fig.6: Flow Diagram of Functioning of Another Embodiment of the Electric Bicycle in Different Modes]

Figure 6, as a variation, a voltage booster (50) circuit is added (106) after three phase rectifier (30) when all the batteries (21, 22,…) are required to be charged simultaneously (107).

IV. RESULTS AND DISCUSSIONS

4.1 An electrical rotating device assisted electric bicycle, derived from a conventional bicycle by providing a redesigned frame and providing a conversion equipment comprising:

4.1.1 The electrical rotating device acting as a motor and a generator, the electrical rotating device mounted on a hub of a rear wheel of the electric bicycle;

4.1.2 A direct current (DC) to pulse width modulating alternating current (AC) converter feeding pulse with modulated (PWM) AC supply to the electrical rotating device when acting as a motor;

4.1.3 A Hall Effect speed controlling device mounted on a handle of the electric bicycle;

4.1.4 A battery chamber containing a plurality of re-chargeable batteries;

4.1.5 A three phase rectifier;

4.1.6 An optional voltage booster; and

4.1.7 A head panel for display and controls disposed on a handle bar of the electric bicycle, wherein the electrical rotating device assisted electric bicycle has at least a Power mode, a Charge mode and a Manual mode.

The electrical rotating device assisted electric bicycle, wherein the redesigned frame has a paddling axis shifted towards a front wheel creating some room near the rear wheel. The battery chamber is a slender rectangular volume created between the rear wheel and a seat support of the redesigned frame. The plurality of re-chargeable batteries is connectable in series or in parallel or disconnected from one another. The electrical rotating device is a commutator-free, brushless rotating device with inverse torque speed characteristics.

The electrical rotating device has a length less than

one third of a diameter of the electrical rotating device. The electrical rotating device is rotatable mounted on an already present hub of the rear wheel of the electric bicycle. The Hall Effect speed controlling device comprises a first permanent magnet , a second permanent magnet and a Hall Effect sensor , the first permanent magnet and the second permanent magnet disposed around a periphery of a circular ring , the first permanent magnet non-movably disposed while the second permanent magnet disposed movably along the periphery of the circular ring with the Hall Effect sensor disposed in between the first permanent magnet and the second permanent magnet, such that the Hall Effect sensor produces a variable Hall voltage VH as the second permanent magnet moves. The head panel for display and controls comprises a selector switch S1, a selector switch S2, indicating lamps, a display panel and a head lamp. In the Power mode, the electrical rotating device acts as a motor and drives the rear wheel, and the plurality of lightweight batteries get connected in series so as to create a DC source which is an input to the DC to AC converter. In the Charge mode, the electrical rotating device acts as a generator, the electrical rotating device produces three phase pulsating waves of voltage when a rotor of the electrical rotating device is made to rotate either by paddling or by any other mechanical means, and through a three phase rectifier, the pulsating voltage is converted to DC for charging the batteries one by one. In the Charge mode, the electrical rotating device acts as the generator, the electrical rotating device produces three phase pulsating waves of voltage when the rotor of the electrical rotating device is made to rotate either by paddling or by any other mechanical means, and through the three phase rectifier, the pulsating voltage is converted to DC for charging the batteries, the batteries being charged simultaneously by deploying the voltage booster after the three phase rectifier. In the head panel for display and controls has a display panel showing a speed of the electric bicycle, a state of head lamp, a state of charge of the plurality of batteries and a health of the DC to AC converter.

V. CONCLUSION

An electric bicycle having a redesigned frame with minimum mechanical changes and produces electric energy needed for its own running. Also this electric bicycle is not weather dependent for producing electric energy. An electric bicycle include electrical rotating device which derived from conventional bicycle, having a redesigned frame with a paddling axis shifted towards the front wheel with conversion equipment comprising the electrical rotating device. Hall effect speed controlling device used with 12v re-chargeable batteries. Electrical rotating device assisted electric bicycle has a power, a charge and manual mode

DECLARATION STATEMENT

After aggregating input from all authors, I must verify the accuracy of the following information as the article's author.

- **Conflicts of Interest/ Competing Interests:** Based on my understanding, this article has no conflicts of interest.
- **Funding Support:** This article has not been sponsored or funded by any organization or agency. The independence of this research is a crucial factor in affirming its impartiality, as it has been conducted without any external sway.
- **Ethical Approval and Consent to Participate:** The data provided in this article is exempt from the requirement for ethical approval or participant consent.
- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
- **Authors Contributions:** The authorship of this article is contributed equally to all participating individuals.

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