Intelligent Battery Control Mechanism for Electric Bicycles

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Abstract*:* Transportation is a basic requirement of humans. Currently, fossil fuels are the main source used in automobiles and the trend is moving towards electric vehicles which is more environmentally friendly. Battery is one of the main components in an electric vehicle. This paper aims to introduce an intelligent battery control system which integrates a dual battery mechanism and four riding modes. Two lithium-ion battery packs with 48V and 16AH each are used. Full electric, pedal assist, neutral and continuous charging are the four driving modes. The pedal assist mode is implemented with new Control mechanism and continuous charging is a new concept to E-bicycles. An alternator is used as an energy harvesting mechanism. The state of charge of each battery pack are automatically detected and pack with lower state of charge is assigned to store the energy harvested from regenerative mechanism. The battery pack with higher state of charge is allotted to drive the bicycle. System will automatically interchange the role of each pack when the driving pack reaches to its acceptable minimum state of charge. Proposed system will allow both battery packs to charge or discharge within its full nominal range which is not linear. Thus, that allows an increase in per charge travelling distance. The inter connection between subpacks are controls through a relay panel based on voltage readings. Finally, the bicycle was subjected to road trials under three drivers with different weights. Proposed system helps to cover 41.6km under electric mode and covers 49.4km in pedal assist mode. Bicycle needs to cover 61km in continuous charging mode to fully charge the battery.

Keywords: *E-bicycle, Dual-Battery Mechanism, Driving modes.*

1. Introduction

Transportation is a basic requirement of people in the present. Almost every family in urban areas has their own vehicle. But, due to lack of space in houses, there's a tendency of increase in usage of smaller size vehicles in the world and as well as in Sri Lanka. Among small size vehicles, two wheelers have become more famous due to several reasons. Affordable price, less parking space, low maintenance, easy to ride are some of those. Nowadays there is a trend in people to move towards E vehicles. But E-bikes or electric bicycles are not a new trend, it has been around for decades. An electric bike is a regular bike with the addition of an electrical drive system. This consists of a battery, a motor, a way to integrate the motor's power into the drivetrain, and a way to control that power. (Krung, 2019) E-bicycles also have limitations like, per charge travelling distance, top speed, battery life span, charging time etc. Among those, this research is focusing on increasing the per charge travelling distance through integrated mechanism of dual battery mechanism with four driving modes. Through the research conducted by Lijun and the team on "Dynamic Lithium-Ion Battery Model for System Simulations" it was observed that the Charging and discharging of Lithium-ion cells are not linear. Figure 1 shows the experimental (Dark line) and simulated (Lighter line) results of above research. It can be observed that the discharge rate at the beginning is low. In the charging cycle also the initial charge rate is lower, which means charging and discharging curves does not coincide. The proposed system allows the batteries to charge and discharge through its full cycles without overlapping. Usually, lithium-ion cells are not discharged up to 0V level. It is also demonstrated through below Figure 1. (Gao , et al., 2002)

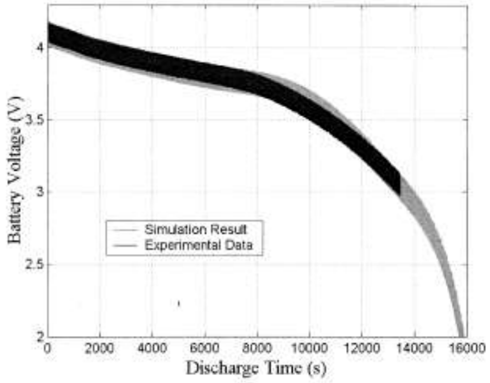


Figure 1. Simulated & Experimented results of 18650 Lithium-ion cell discharge cycle.

Source: (Gao , et al., 2002)

2. Methodology

Online research based on research, leading brands and local market research was carried out to collect data on electric bicycles, battery charging mechanisms, energy harvesting mechanisms, rechargeable cell chemistry and geometry, battery management systems, bicycle chassis simulation methods, bicycle motor controllers, and driving modes. Based on the collected data, design consideration was one of existing techniques and methods to make this research distinctive. Based on results of the design consideration, conceptual designs were done. Calculations, 3D modelling, Material selection and design simulations were carried out simultaneously as shown in the Figure 2. Calculations were carried out to select the motor and the controller. Some modifications were done in calculations and selected 3D model based on the simulations and available components and materials. The finalized design was fabricated in a workshop. Then the prototype was subjected to road trials. A mobile app was used to take track the route, the distance travelled and to measure the top speed. Voltage readings were noted, and results were evaluated.

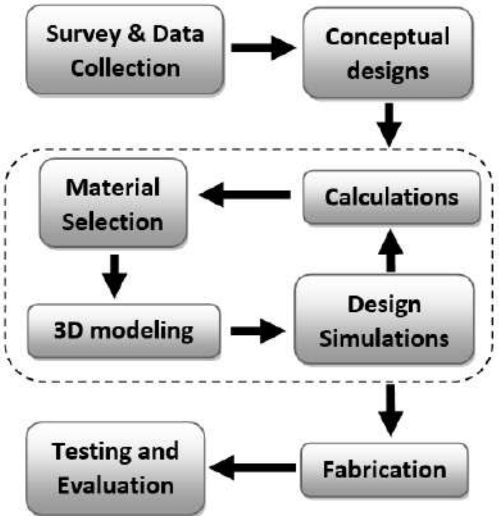


Figure 2. Methodology of the research.

Source: Designed by authors.

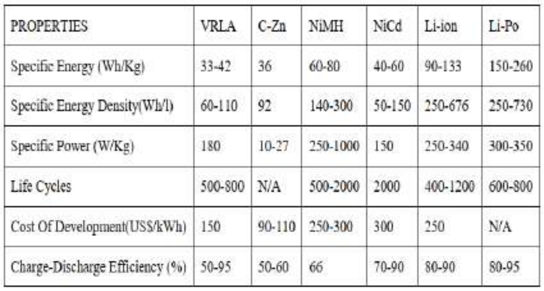
3. Design, Simulation and Testing

A. Battery Pack and Control Circuit

One of the most important parts of an electric bicycle is the battery pack. It is because the performance of the bicycle dependent on it. Currently, Variable Regulated Lead Acid Battery (VRLA), Nickel Cadmium (NiCd), Carbon Zinc (C-Zn), Lithium Ion (Li-Ion), Lithium polymer (LiPo) are some of the cell types available in the industry. When selecting a suitable battery type for an electric vehicle, Energy Density (Wh/kg), Specific Energy (Wh/I), Power Density (kW/kg), Charging and Discharging timing, life cycles and eco friendliness like specifications were considered. The Table 1 shows a summary of properties of each cell type according to the research done by Ashish. (Ashish, et al., 2016)

Based on data in Table 1 it could be observed that Li-ion has higher specific energy that only seconds to Li-Po. Also, Li-ion has a comparatively higher specific power and charge discharge efficiency. According to the report “Design and Analysis of a Battery for a Formula Electric Car” done by Samuel Reineman, MIT, has mentioned that “getting maximum energy and power from lowest mass possible is a main factor when choosing a proper power source for an EV. The acceleration is depending on the power and travelling distance is depending on the energy is important. To get high energy and high power from low mass, cells with higher specific energy (Wh/kg) and higher specific power (W/kg) are suitable.” (Reineman, 2013). Figure 3 shows the comparison between specific power and specific energy. Lithium-ion cells shows more prominent features among cell types.

Table 1. Properties of cells used in Electric Vehicles.



PROPERTIES	VRLA	C-Zn	NiMH	NiCd	Li-ion	Li-Po
Specific Energy (Wh/Kg)	33-42	36	60-80	40-60	90-133	150-260
Specific Energy Density(Wh/l)	60-110	92	140-300	50-150	250-676	250-730
Specific Power (W/Kg)	180	10-27	250-1000	150	250-340	300-350
Life Cycles	500-800	N/A	500-2000	2000	400-1200	600-800
Cost Of Development(US$/kWh)	150	90-110	250-300	300	250	N/A
Charge-Discharge Efficiency (%)	50-95	50-60	66	70-90	80-90	80-95

Source: (Ashish, et al., 2016)

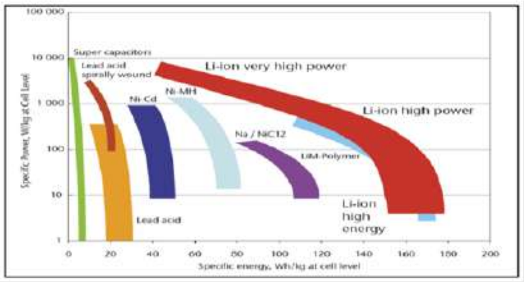


Figure 3. Cell Comparison (Specific Power vs. Specific Energy).

Source: (Reineman, 2013)

Among the lithium iron cells with different geometrical shapes, 18650 cells were chosen because of its flexibility in designing a custom shaped battery pack. Motor selection was done considering the acceleration force, rolling resistance, grade resistance, and air drag. Based on the calculations, required motor was 48V 500W BLCD motor. Thus, the battery pack was designed in 48V and 16 Ah to achieve the maximum per-charge distance. Based on following equations, a model was developed to calculate the number of cells required.

Calculation consideration,

- Expected Nominal Battery pack voltage = 48V
- Battery cell Nominal voltage = 3.7V
- Battery Cell Capacity = 2.2Ah
- Peak C-rate of a cell = 2C
- Continues C-rate of a cell = 1C
- Average Energy Consumption per km = $12 \mathrm{whkm}^{-1}$
- Per charge distance = 35km

$$(E_{bc}) = (C_{bc}) \times (U_{bc}) \quad \ldots\ldots (1)$$

$$(E_{bp}) = (E_{Avg}) \times (D_v) \quad \ldots\ldots (2)$$

$$(N_{cs}) = ((U_{bp}))/((U_{bc})) \quad \ldots\ldots (3)$$

$$(E_{bs}) = (N_{cs}) \times (E_{bc}) \quad \ldots\ldots (4)$$

$(N\_sb) = (\llbracket(E\rrbracket\ \_bp))/(\llbracket(E\rrbracket\ \_bs))$ …………………………………………………… (5)

$(C\_bp) = \llbracket(N\rrbracket\ \_sb) \times (C\_bc)$ ………………………………………… (6)

$(N\_cb) = (N\_sb) \times (N\_(cs))$ ………………………………………… (7)

$(I\_spc) = \llbracket(C\rrbracket\ \_(rate\ bcp)) \times (C\_bc)$ ………………………… (8)

$(I\_bpp) = (I\_spc) \times (N\_(sb))$ ……………………………… (9)

$(P\_bpp) = \llbracket(I\rrbracket\ \_bpp) \times (U\_bp)$ …………………………………(10)

$(I\_scc) = \llbracket(C\rrbracket\ \_(rate\ bcc)) \times (C\_bc)$ ……………………………(11)

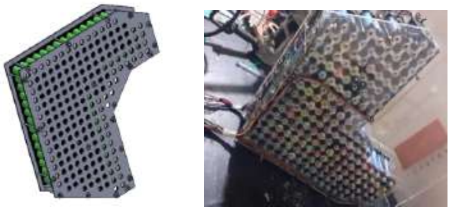
$(I\_bpc) = (I\_scc) \times (N\_sb)$ ……………………………………(12)

$(P\_bpc) = (I\_bpc) \times (U\_bp)$ …………………………………(13)

- Battery Cell Energy = E_{bc}
- Battery cell Capacity = C_{bc}
- Battery cell voltage = U_{bc}
- Battery Pack total Energy = E_{bp}
- Average Energy consumption = E_{Avg}
- Vehicle range = D_{v}
- No of cells connecting in series = N_{cs}
- Nominal battery pack voltage = U_{bp}
- Energy content in of a series string = E_{bs}
- Required no of Strings = N_{sb}
- Battery pack Capacity = C_{bp}
- No of cells of the pack = N_{cb}
- String peak current = I_{spc}
- Peak C - rate of a cell = $C_{rate\ bcp}$
- Pack peak current = I_{bpp}
- Pack peak Power = P_{bpp}
- String continuous current = I_{scc}
- Continuous C-rate of a cell = $C_{rate\ bcc}$
- Pack continuous current = I_{bpc}
- Pack continuous Power = P_{bpc}

Based on the calculations 192 cells were needed for the battery pack. As the space available in the bicycle is limited, a custom shaped battery pack was modelled using Solidworks. Then the batteries used in the project was subjected to internal resistance test and capacity test. The sub battery packs were spot welded and kept for top balancing before connected to BMS's. Through internal resistance test it is checked whether the batteries discharge themselves. For capacity test, 18650 battery discharger is used where batteries are discharged under a constant current through a resistor. The Final voltage of the battery pack was 48V and capacity was about 16mAh.

Nickel plates are used to spot weld the battery connections in sub-battery packs as shown in Figure 4. For each sub battery pack, a BMS and a voltage sensor is connected. Eight BMS units were connected to the 16-relay panel through higher gauge wires as it switches supply with higher amperages.



(a) (b)

Figure 4. (a) 3D model (b) Fabricated battery pack

Source: Designed by authors.

Battery switching circuit monitor the voltages of each battery pack and battery with higher voltage is assigned to drive bicycle and other pack is used to store the energy harvested from the bicycle. The circuit is automatically switching the role of each battery pack when the driving pack reaches its accepted minimum discharge limit. Proposed circuit is allowing each battery pack to charge or discharge within its full range. As the battery pack is 48V, the supply from alternator (13.5) (Energy Harvesting Mechanism) needs to be converted to 48V using DC-DC converter which would limit the maximum current supplied to the battery pack. Thus, that could result in increase in charging time. As a solution, each battery pack was again divided into four 12V sub-battery packs to charge directly from alternator. To interchange the connectivity between 12V packs to obtain 48V when discharging and 12V when charging, a relay circuit is introduced. Relay circuit was designed and simulated through Proteus software, and it was optimized to 16 relays. Figure 5 shows the block diagram of battery switching circuit.

B. Driving Modes and Control circuit

There are many different types of electric bikes with different ways of activating the electric assist. According to the way which the electric bike use the electric assist E bike have their modes. For that they use different throttle types (twist grip, thumb, push button), pedal assist types (torque sensor and cadence sensor) and user can choose different modes by those. In this model, four driving modes as Electric, Pedal assist, Neutral and continuous charging are introduced. Engagement of motor and the alternator is different in each mode.

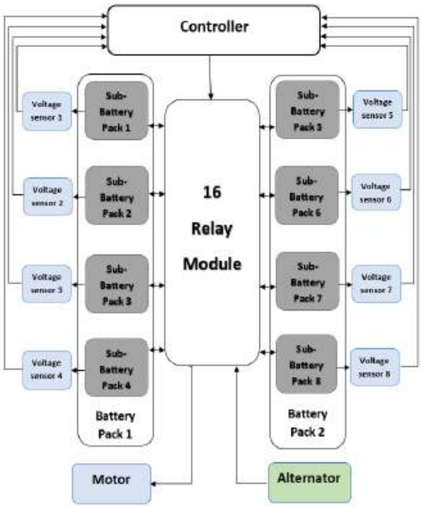


Figure 5. Battery switching circuit.

Source: Designed by authors.

The Electric mode is similar to how a motorcycle or scooter operates. When the throttle is engaged the motor provides power and propels you and the bike forward. A throttle allows you to just kick back and enjoy a “free” ride. According to “Electric Bike Modes: Throttle vs. Pedal Assist” (Zhu, 2018), “A lot of E-Bicycles in the US have bike is not allowed; only pedal assist”. “Twist Throttle”, “Thumb Throttle” and “push button throttle” are currently available in Electric bicycles as throttle options. In this E-Bicycle, the Twist throttle type is used. Thus, there will be no connection between paddling and the motor. Motor will only consider the input from throttle and act accordingly.

Pedal assist is another mode that provides power only when you are peddling. The pedal assist mode will generally give you more range when compared to the throttle mode. With the development in E-bicycle field, different types of sensors like torque sensors, speed sensors and cadence sensors are being used to take the input for assist mode. In this model, an IR sensor is used with encoder wheel which is with 96mm diameter and 80 pulse per turn for the speed sensor. To detect the peddling effort/speed, following equations were used to calculate the peddling velocity via Encoder IR Sensor Module shown in Figure 6.

$$rpm = ((60 \times 1000)/(pulses\ per\ turn)) \tag{14}$$

$$velocity\ (kmph) = ((rpm) \times \pi \times (d) \times 60)/1000000 \tag{15}$$

Based on the calculated velocity, scaled pulse is given to the motor controller to drive the motor. A separate relay is used to bypass the throttle signal and connect scaled pulse from controller when pedal assist mode is actuated.

Continuous Charging is the next driving mode which is introduced in this model. This mode is also actuated by rider preference. The energy harvesting mechanism, or the alternator is continuously engaged to the drive strain to charge the batteries. The alternator engaging and disengaging mechanism briefly engaged in under “Engaging and Disengaging Mechanism of motor and alternator”.

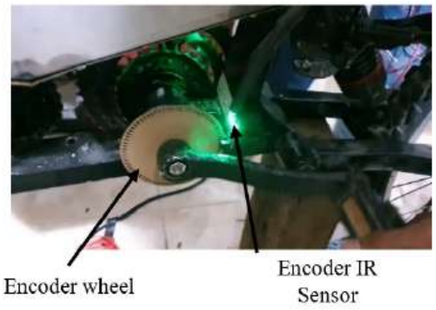


Figure 6. IR Sensor and Encoder wheel.

Source: Designed by authors.

Final driving mode is the neutral mode, which is similar to a conventional bicycle. Both motor and alternator will be disengaged from the driving strain in this mode.

A slope detection mechanism is added to the bicycle, which is a unique feature to actuate the energy harvesting mechanism while moving on a slope. A Gyroscope sensor was used for this purpose and trials were carried out on a conventional bicycle and on a motor bike to simulate the real conditions and to detect the threshold level to detect a slope. This feature is actuated in any mode and will help to reduce the speed of the bicycle and charge battery. Likewise, the Alternator is also actuated in any mode when brakes are applied. Brake sensors will give the signal to the controller and that will actuate the alternator clutch. Figure 7 shows a block diagram with inputs and outputs connected to controller to actuate driving modes.

C. Engaging and Disengaging Mechanism

The reason of implementing an engaging and disengaging mechanism for mid driven motor and alternator (Energy Harvesting mechanism) is to avoid unwanted drag on rider. Since both motor and an alternator are used in the model, the drag would be doubled. As a solution, the electro-magnetic clutch mechanism was selected due to its inbuilt mechanism to engage and disengage clutches. Usually, the electromagnetic clutches are used in AC compressors of automobiles, correct alignments when coupling is critical. So, the motor, alternator and the EM-clutches were 3D modelled using SolidWorks software to do the development.

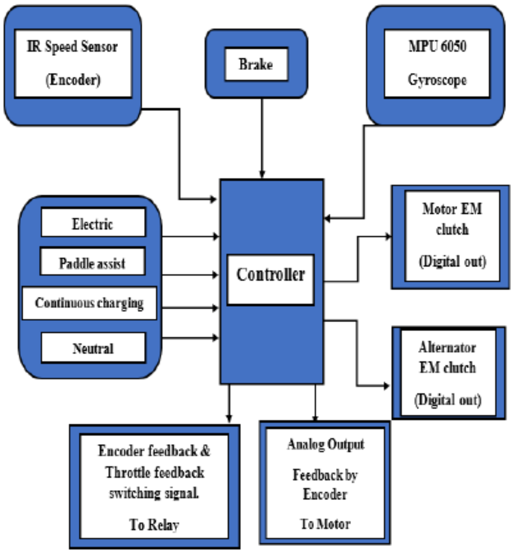


Figure 7. Driving modes control circuit.

Source: Designed by authors

Then the models were modified to a cassette wheel driving mechanism as shown in Figures 8 and 9. Main concerns in this designing were to maintain proper alignments in the motor, alternator, and EM clutch shafts and to maintain concentric positioning between cassette wheel and shafts.

Table 2 shows a summary of Motor and alternator engagement in each driving mode.

Table 2. Motor an alternator engagement in different modes.

Mode	Motor	Energy harvesting Mechanism (Alternator)
Electric (throttle) Mode	Fully engaged, released only in slopes and when brakes applied.	Engaged only in sloped and when brakes applied.
Pedal Assist Mode	Engaging only with encoder signal, released in slopes and when brakes applied.	Engaged only in sloped and when brakes applied.
Continuous charging Mode	No engagement.	Continuously engaged.
Neutral mode	No engagement.	Engaged only in sloped and when brakes applied.

Source: Designed by authors.

4. Results and Discussion

The main aim of this research is to introduce an Intelligent Battery Control system integrated with Dual battery mechanism and driving modes. The project was categorized in to sub sections to reduce the complexity in developing each section. Since each sanction is crucial for the success of the project, it was always concerned to do the fabrications aligned with the design.

The batteries used in the project was subjected to internal resistance test and capacity test. Through internal resistance test, the batteries below 4.0V and batteries bellow 2200mAh after capacity test were not used. Initial battery switching circuit had 22 relays and after simulation it was optimized to 16 relays.

Then the working prototype, as shown in Figure 10, was subjected to road trials in different modes. A mobile app was used to measure the travelled distance, top speed, and the route. The results are as follows.

D. *Electric (Throttle) mode*

To compare the introduced system, few trials were conducted without the system in same bicycle. The per-charge distance without the system was 34.4 km. That means the charging and discharging is undertaken by same battery pack. Thus, the charging and discharging cycles are overlapped. Under the proposed system, eight trials were conducted, and the trial results are given in Table 3.

Table 3. Summary of trial results under Electric mode.

Trial	Initial Voltage (P1)	Final Voltage (P1)	Initial Voltage (P2)	Final Voltage (P2)	Distance Covered
1	49.52	47.12	44.42	44.50	4
2	47.10	44.05	44.50	45.12	5
3	4.05	41.52	45.12	45.71	4.5
4	41.50	38.96	45.71	46.83	4.5
5	38.95	36.55	46.83	46.50	5
6	36.55	37.14	46.50	44.23	4
7	37.14	37.51	44.23	41.92	4
8	37.51	38.12	41.92	39.85	3.5

Source: Developed by authors.

Through above trials, it was observed that per charge distance as 41.6 km and it is about 19% increase in per charge distance.

(a) (b)

Figure 8. (a) 3D model, & (b) alternator coupled with EM clutch.

Source: Designed by authors.

(a) (b)

Figure 9. (a) 3D model & (b) motor coupled with EM clutch.

Source: Designed by authors.

E. *Pedal assist mode*

Five trials were conducted under pedal assist mode covering 11km.The per charge distance was calculated based on the collected data as 49.4 km. Though this is more than the full electric mode, the expected per charge distance under pedal assist mode was 55km. This may be based on the road conditions. Table 4 shows the summary of trial results under pedal assist mode.

Table 4. Summary of trial results under Pedal assist mode.

Trial	Initial Voltage (P1)	Final Voltage (P1)	Initial Voltage (P2)	Final Voltage (P2)	Distance Covered
1	46.23	45.33	39.22	39.23	2
2	45.33	44.20	39.23	39.65	2.5
3	44.20	43.31	39.65	39.89	2

4	43.31	42.12	39.89	40.24	2.4
5	42.12	40.18	40.24	40.41	2.1

Source: Developed by authors.

F. *Continuous charging mode*

Under continuous charging mode, alternator is always engaged with the drive train. Due to that, paddling was bit difficult. Thus, the short trials were conducted covering 3.7km. Thus, the rider needs to ride almost 61kms to totally charge under this mode. Table 5 shows a summary of trial results under continuous charging mode.

Figure 10. Prototype of the E-bicycle

Source: Designed by authors.

Table 5. Summary of trial results under Continuous charging mode.

Trial	Initial Voltage (P1)	Final Voltage (P1)	Initial Voltage (P2)	Final Voltage (P2)	Distance Covered
1	42.62	42.62	39.43	39.88	1
2	42.62	42.62	39.88	40.42	1.2
3	42.62	42.62	40.42	41.13	1.5

Source: Developed by authors.

5. Conclusion and Recommendations

This research is to implement an intelligent battery control mechanism which is an integration of dual battery mechanism with four driving modes. Here the rider could choose the driving mode they prefer. Based on the trials conducted in electric mode, integrated system has improved the per charge travelling distance from 34.4 to 41.6 km. So, it has improved per charge travelling distance by 19%. By fabricating the bicycle chassis using a much lighter material, the per charge distance could be improved. Though the pedal assist mode is a common mode in electric bikes, a new mechanism to measure riders' input and assist the paddling is introduced here. The per charge travelling distance in pedal assist mode is 49.4km, which could be higher in flat roads like Colombo. Continuous charging mode is a unique feature in this bike, where if any rider needs to burn extra calories, it will be a side benefit. It is observed that if rider needs to fully charge the battery only from continuous charging mode, it takes 61 kms. This could be reduced using a much-developed alternator and using a mechanism to improve the rpm of the alternator. From the statistics produced, it can be concluded that the introduced mechanism has improved the per charge distance of the E-bicycle.

References

Abagnale, C; Cardone, M; Idoice, P & Marialto, R (2016): Design and Development of an Innovative E-bicycle, Energy Procedia, 101, pp. 774-781.

Ashish, U, Bishav, R & Kumar, A (2016): Design and Fabrication of an accumulator container/ Battery pack for a formula student vehicle, International Journal of Research in Engineering and Technology, 05(03).

Belekar, R; Subramanian, S; Panvalkar, P V; Desai, M and Patole, R (2017): Alternator charging system for Electric Motorcycles.

International Research Journal of Engineering Technology, 04(04), p. 1759-1766.

Chandratre, A; Saini, H; Vemuri, S H & Srinivas, M (2011): 'Battery Management Syatem for E-bike: A Novel Approach to Measure Crucial Battery Parameters for a VRAL Battery,' India International Conference on Power Electronics 2010 (IICPE2010).

Cheng, Y C; Lee, C K; & Tsai, M T (2016): Multi objective optimization of an on-road bicycle frame by uniform design and compromise Programming, Advances in Mechanical Engineering, 8(2), pp. 1-15.

Covill, D; Begg, S; Elton, E; Milne, M; Morris, R and Katz Tim (2014): 'Parametric Finite element analysis of bicycle frame geometries,' Conference of the International Sports Engineering Association, 72, pp. 441-446.

Gao , L; Liu, S & Dougal, R A (2002): Dynamic Lithium-ion Battery model for system simulation, IEEE Transactions on Components and Packaging Technologies, 25(3).

Hsu, C; Yu, C; Chao, S and Huang, M C J (1989): Electric Bicycle. U.S. Patent 4871042.

Hunt, I A; Zhao, Y; Patel, Y & Offer, G (2016): Surface Cooling Causes Accelerated Degradation Compared to Tab Cooling For Lithium -Ion Pouch Cells, The Electrochemical Society, 9, p. 163.

Krung, F, n.d. Electric Bikes vs Regular Bikes: The real Difference by EVElo. [Online] Available at: https://www.evelo.com/blog/electric-bikes-vs-regular-bikes/
[Accessed 17 February 2020].

Li, Z; Zuo, L; Luhrs, G; Lin, L & Qin, Y (2013): Electromagnetic Energy-Harvesting Shock Absorbers: Design, Modeling and Road Tests, IEEE transactions on vehicular technology, 62.

Maughan, R (2017): What is the Best Electric Vehicle Battery Cooling System.

Pellitteri, F; Boscaino, V & di Tommaso, A C (2013): E-bike battery charging: methods and circuits, 2013 International Conference on Clean Electrical Power (ICCEP).

Rashid, M I M & Osman, J R A J (2017): 'Design and Implementation of Battery Management System for Electric Bicycle;, MATEC Web of Conference.

Reineman, S (2013): Design And Analysis of a Battery For a Fomula Electric Car, Massachusetts Institute of Technology.

Saw, L H; Ye, Y & Tay, A A (2015): Integration issues of lithium -ion battery in to electric vehicle battery pack, Journal of cleaner Production.

Vasic, D; Chen, Y -Y & Costa, F (2013): Self-Powered Piezoelectric Energy Harvester for Bicycle. IECON 2013 - 39th Annual Conference of the IEEE Industrial Electronics Society, pp. 1856-1861.

Yang, Y; Yeo, J & Priya, S (2012): Harvesting energy from the Counterbalancing (Weaving) Movement in Bicycle Riding. Sensors, 12, pp. 10248-10258.

Abbreviations and Symbols

DC – Direct Current

E-bicycle – Electric bicycle

SOC – State of charge

DOD – Depth of Discharge

SOH – Sate of Health

Li-Ion – Lithium Ion

Ni-Cd -Nickel Cadmium

VRLA – Variable Regulated Lead Acid Battery

NiMH - Nickel Metal Hydride

C-Zn – Carbon Zinc

LiPo – Lithium Polymer

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