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The Conversion of an Internal Combustion Engine Motorcycle to a Full Electric Motorcycle: The Challenges and Opportunities

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Abstract: In Nigeria, practically all forms of transportation including cars, motorcycles, trains, buses, etc. use internal combustion engines (ICEs) that are propelled by either gasoline or diesel fuel. Vehicles with internal combustion engines are more likely to cause environmental pollution, which has negative impacts on climate change. To reduce the negative consequences of ICE consumption, there is urgent need to switch to a more efficient but low fossil fuel consumption. This idea involves conversion of functional motorcycle powered by gasoline internal combustion engine into an electric motorcycle. This is consistent with the steps taken to use clean energy and lessen environmental degradation agents. The motorcycle's ICE components (engine, exhaust, and rear wheel) must be disassembled as part of this process. In addition, a battery (a form of energy storage), a motor controller, and an electric wheel motor hub the latter of which acts as the motorcycle's engine were installed. The battery and motor hub have the following specs: a lithium ion battery with a voltage of 48 volts and a current of 26 amps, a 1.5 KW electric wheel hub. Depending on the rider's weight, the battery might last up to 3 hours when in use at an average speed of 30 km/h. The motorcycle's speed, range, and operating duration are all dependent on the load it is carrying and the battery capacity. The use of an electric motorcycle is significantly more cost-effective and environmentally beneficial, and it is simple to operate and maneuver. Because it will run longer and travel farther, increasing the motor specification and battery capacity further boosts efficiency. Adopting electric vehicles in Nigeria will pave a way for utilizing cleaner energy in the transportation sector. With further development and research, it could be an economically viable project.

Keywords: *Sustainable Energy, Battery Management System, Electric Motorcycle, Internal Combustion Engine, Powertrain and Brake Systems.*

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I. INTRODUCTION

Brouwer et al. (2013) predicted that Electric vehicles in the near future will play an invaluable role in reduction of harmful emissions while increasing energy consumption. According to this prediction, the global increment in energy consumption will rise by 30% and greenhouse emission decline will be 25-60%.Electric vehicles have been in use over the past two hundred years, with several prototypes developed in the late-1800s, but not until the 2000s were highway-ready options available at widespread locations around the world. However, due to limited storage capacity in batteries and improvements in the internal combustion engines, attention for electric vehicles decreased (Kittner et al, 2020).

There are various concepts of electric vehicles, they are; hybrid electric vehicles and full electric vehicles. Hybrid electric vehicles can also be divided into three (3); the full, the mid and the plug-in hybrid vehicles. The full electric vehicles uses only the electrical energy stored in the batteries to run the motor. The full-hybrid electric vehicle uses the internal combustion engine to charge the batteries, the mid-hybrid electric vehicles uses both the ICE and the electric

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batteries and the plug-in hybrid electric vehicle needs to be plugged into the mains in order to be recharged fully to power the drivetrain for motion. An electric vehicle consists of three major subsystems; the energy source subsystem, the auxiliary subsystem and the electric propulsion subsystem. The electronic propulsion subsystem comprises of electronic controller, the power converter, the mechanical transmission and the electric motor. For this project, our focus will be on the conversion of an internal combustion engine motorcycle to a full electric motorcycle, while considering the power train, steering and braking system the electric motorcycle (Delfim Pedrosa, 2014).

Internal combustion engine (ICE) has grown popular over years in its applications to various vehicle designs and various forms of innovations have occurred over the last century in its efficiency. Not neglecting its vast potential in the transport industry, recent movement by environmental activist and government policies has shown that the vast advantage of the ICE does not fully complement its various adverse effects to the world. Adverse effects such as, gas emission, various forms of environmental pollution, climate change and an increasing rate in fossil fuel power consumption are various reasons why researchers have been looking for a suitable substitution for the ICE.

The concepts of electric vehicles have been growing ever since the last few decades and has shown fair prospect in substituting the ICE. Electric vehicles share pretty much the same systems as ICE vehicles, but the major difference being the powertrain and the drivetrain. The powertrain of the EV uses an electric motor as its prime mover unlike the ICE vehicle which uses an internal combustion engine. Generally, electric vehicles (EV) have more advantages in contrast to their combustion counterparts. They are much faster due to the high torque produced, also they are lightweight and energy-efficient, environmentally friendly, have better performance benefits, and have a better sense of reliability. The aim of this research project is to convert an internal combustion engine motorcycle to a full electric motorcycle.

II. MATERIALS AND METHODS

A. Design Consideration

Understanding the parameters which influence motorcycle handling and performance are crucial for design engineers to effectively design for the intended type of use and to satisfy user requirements. The main functions of motorcycle operation are acceleration, steering and braking. Hence it is important to know the; motorcycle structure, part functionality, electric power train technology, motorcycle dynamics and characteristics.

Fundamental aspects such as energy efficiency, safety, technical innovation, cost, strength, and ease of assembly all have an impact on the design in order to fulfill the suggested standard. Given the complexity of the intended design, it is crucial that the right materials be chosen and that the system process be configured in order to accomplish the desired design.

As a result, in order to accomplish the necessary specifications with regard to the fundamental variables, the design will involve the use of computer design simulation tools, design calculations, and fabrication procedures intended to achieve weight reduction.

B. Design Concept

The first step in the design of the vehicle is the conceptual stage where the major requirements are transferred into engineering characteristics.

➢ *Essential Criteria are as Follow:*

- A disassembled fuel running motorcycle.
- Carries only two persons (with the rider inclusive).
- Should be comfortable for the rider.
- It should be able to carry a fair amount of loads.
- Eliminate carbon emission.
- Reliable efficiency and traction.
- Must be free from risk.
- And most importantly, it is to be used for transportation purpose.

- *Design Concept Selection*

A feasibility study of the various alternative designs was carried out in order to carry out a valid design concept selection. These designs are classified as follows:

✓ Powertrain and drivetrain system: To enable motion, this system is in charge of storing, converting, and transmitting energy to the motorcycle's wheels. It functions as both the motorcycle's engine and the system that delivers power.
✓ Braking system: The objective of the braking system is to slow down and/or stop the vehicle. Friction is used to do this. The brake is made to be able to prevent motion by soaking up energy from a moving system.

- *Alternative Designs*

Powertrain and drivetrain: The following are some alternative powertrain system designs:

✓ Powertrain for a fully electric motorcycle.
✓ Powertrain for hybrid electric motorcycle.
✓ The powertrain of an internal combustion engine.

Braking system: For the brake system:

✓ Electric brakes.
✓ Pneumatic brakes.
✓ Hydraulic brakes.
✓ Wire brakes.

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- *Design Selection*

Table 1 Alternative Designs and Design Selection

Considerations	Alternative Designs				Selection
	A	B	C	D	
Powertrain system	Full electric motorcycle	Hybrid electric motorcycle	Internal combustion motorcycle	----	A
Brake system	Electric brakes	Pneumatic brakes	Hydraulic brakes	Wire brakes	C

Table 2 Material Selection for Machine Parts.

S/N	Machine Parts	Material Used	Reason
1	Electric wheel hub	Brushless gearless	Low cost, Energy efficient, High power density, Reliable.
2	Battery	Lithium ion cells	Reliable and affordable.
3	Transmission	Mild steel	Ability to withstand shear and bending forces.
4	Frame/ Chassis	Aluminum alloy	Low weight, high strength, durability, ductility, corrosive resistance, cost effective.

C. Computer Design and Model Using Solidworks

Modeling the motorcycle with aluminum alloy is done using SolidWorks. The motorcycle's aerodynamics, rider comfort, and visibility were all taken into account when developing the model that determines the motorcycle's shape and design.

The final design as well as the design's stated dimensions are presented in the figures below. These measurements were utilized in the construction of the vehicle body; they aid in determining the plug dimensions and in the placement of vehicle components such as the engine and tire configuration.

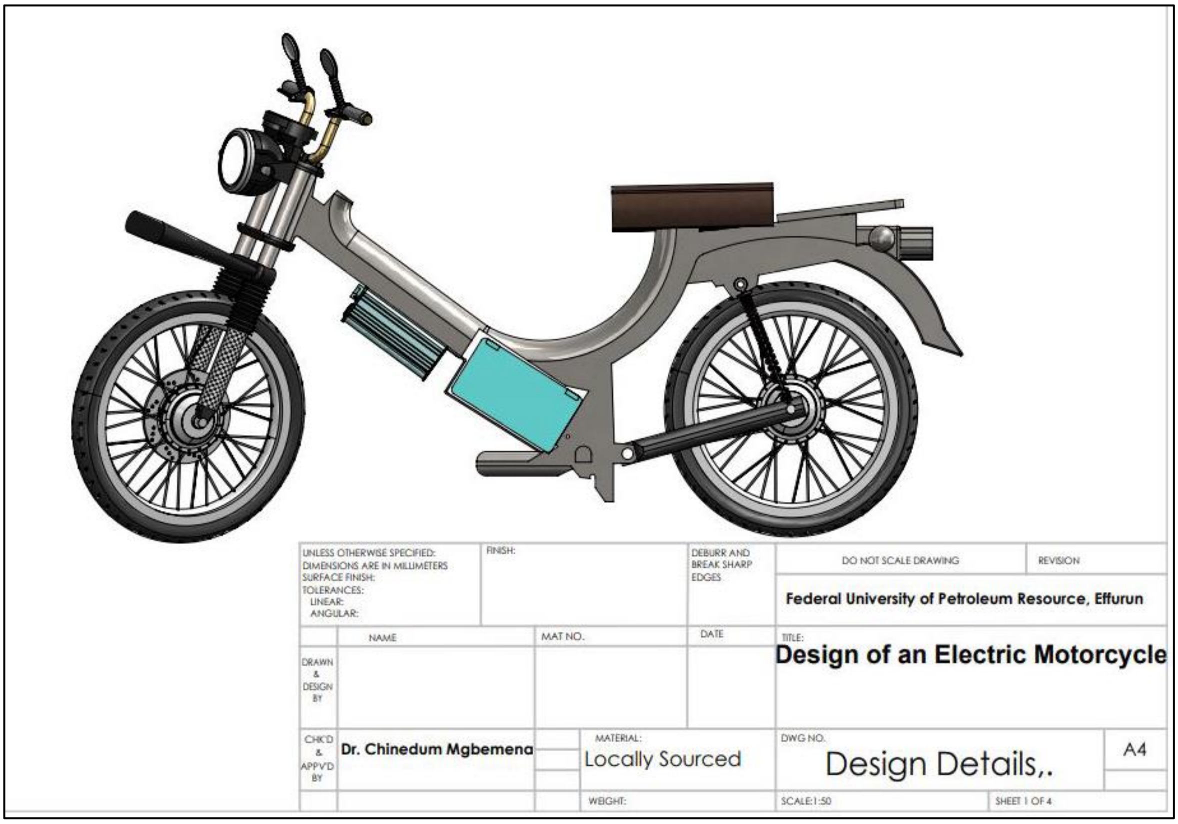

Fig 1 Body Design of the Electric Motorcycle

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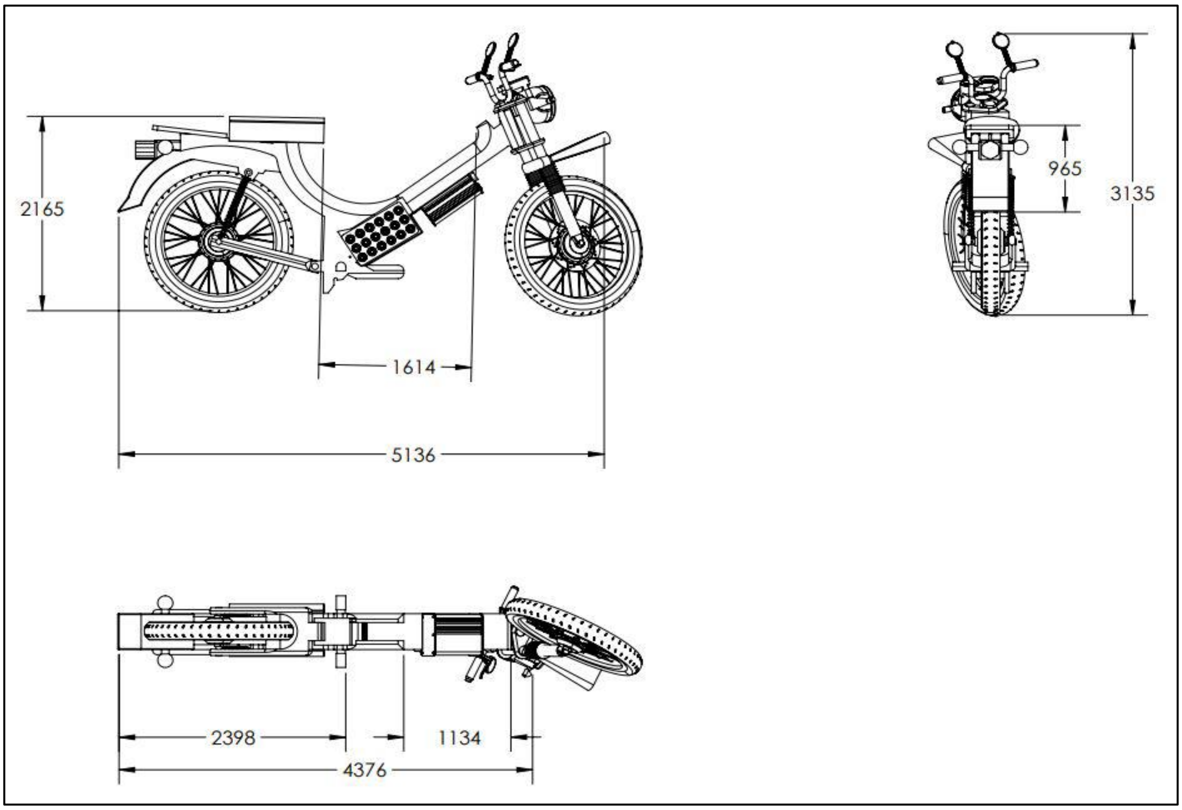

Fig 2 Body Design of the Electric Motorcycle Showing Dimensions

D. Algorithm Used for the Simulink

This process would be divided into four parts namely; the vehicle body, the motor and controller, the drive input and the battery. The following are the process for each input after opening MATLAB and SIMULINK:

➢ *The Vehicle Body Includes:*

- Add vehicle body block
- Input vehicle body block parameters
- Input two tire blocks
- Connect both tire blocks to the vehicle body
- Input tire block parameters
- Add differential block
- Add simple gear block
- Input differential and simple gear block parameters
- Add scope and display blocks
- Add PS block
- Connect scope and display blocks to the vehicle block
- The motor and controller:
- Add DC-motor block
- Add H-bridge block
- Add current sensor block
- Connect the H-bridge to the current sensor
- Connect the motor block to the simple gear box block
- Add control PMW voltage block parameters
- Add scope block
- Add PS block
- Add electrical reference block
- Connect all negative references to the ground block
- Add solver configuration block

➢ *The Drive Input Includes:*

- Add longitudinal driver block
- Input longitudinal driver block parameters
- Add constant block
- Add SP converter block
- Add controlled voltage source
- Connect all reference poles
- Add signal builder block
- Create signal
- Connect actual speed to feed-back velocity
- Add one more port to the vehicle body scope
- The battery:
- Add battery block
- Add parameters to battery block
- Add bus selector block
- Input bus selector parameters
- Connect scope and display to each bus selector port
- Add control current source
- Connect to the battery and the H-bridge blocks
- Add power gui block
- Run simulation for preferred time limit

E. Design of Brake System

➢ *Brake System*

The most crucial component of a car is its braking system. The brakes are always handled with the highest care and regularly inspected in all automobile designs because their failure could result in the loss of lives and property. It could end badly if the brakes don't work. In reality, brakes are

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energy conversion tools that transform the kinetic energy (momentum) of your car into thermal energy (heat). When you apply the brakes to your car, you can command a stopping force that is up to ten times as strong as the force that propels it forward. Each brake can be under thousands of pounds of strain from the braking system.

Fig 3 Picture of the Electric Motorcycle Brake being Fixed

➤ *Braking Force*

Mass of the motorcycle, $m_1 = 100kg$

Mass of rider, $m_2 = 70kg$

Total mass of motorcycle in motion, m = 170kg

Velocity, v = 25km/hr = 6.94m/s

Using the relation, one may determine the vehicle's kinetic energy as a function of its motion.

$$K.E = \frac{mv^2}{2}$$

Where m is mass in kg and v is velocity in m/s.

Therefore,

$$K.E = 4.09kJ$$

Since the main goal of braking is to transform the kinetic energy of the moving motorcycle into heat energy produced in the hub. The entire amount of kinetic energy is transformed to heat energy, which is ultimately lost to the atmosphere as a result of temperature differences. This suggests that the amount of effort done by the brakes throughout the stopping distance must be equal to the motorcycle's kinetic energy.

$$Workdone\ by\ brakes = K.E\ possessed\ by\ vehicle$$

The relation below can be used to get the workdone by the brakes and that gives:

$$Workdone\ by\ brakes = braking\ force \times stopping\ distance$$

In comparing equation and the braking force, we have:

$$Braking\ force = \frac{K.E\ possessed\ by\ motorcycle}{stopping\ distance}$$

$$Braking\ force = \frac{4093}{15} = 272.86N$$

The force that the rider must apply in order to provide the motorcycle with the necessary force is given by dividing this braking force by the amplification factor, or force F.

$$F = \frac{272.86}{35} = 7.79N$$

This merely means that by applying a small force of 8N to the brake lever, even more braking force than is necessary will be obtained from the brakes.

F. Engine and Power Transmission

➤ *Motor Specification*

The project's nature necessitates that when choosing an electric wheel hub, a number of factors must be taken into account in order to provide a competitive edge. The cost, load profile, speed control, torque, and motor speed were all taken into account. The size, weight, and noise of the electric wheel hub were also taken into consideration. Every application has a different use case, thus the operational parameters were given priority even if certain factors couldn't be addressed in the best way because there will inevitably be some compromises. The decision was made in light of the literature assessment and the expertise of master craftspeople. With the specifications listed below, a brushless gearless DC wheel hub electric engine was acquired;

➤ *Battery Management System (BMS)*

Lithium-ion battery have high charging efficiency. Battery SOC evaluation plays a primary role in battery systems. The state of charge can only be estimated indirectly which needs to be estimated with the help of information such as voltage, current, internal resistance, and temperature.

The state of charge of a battery is the level of charge of an electric battery relative to it capacity. State of charge is usually represented in percentage.

For a 48V 26Ah battery: at 55.8V, the battery is 100% fully charged.

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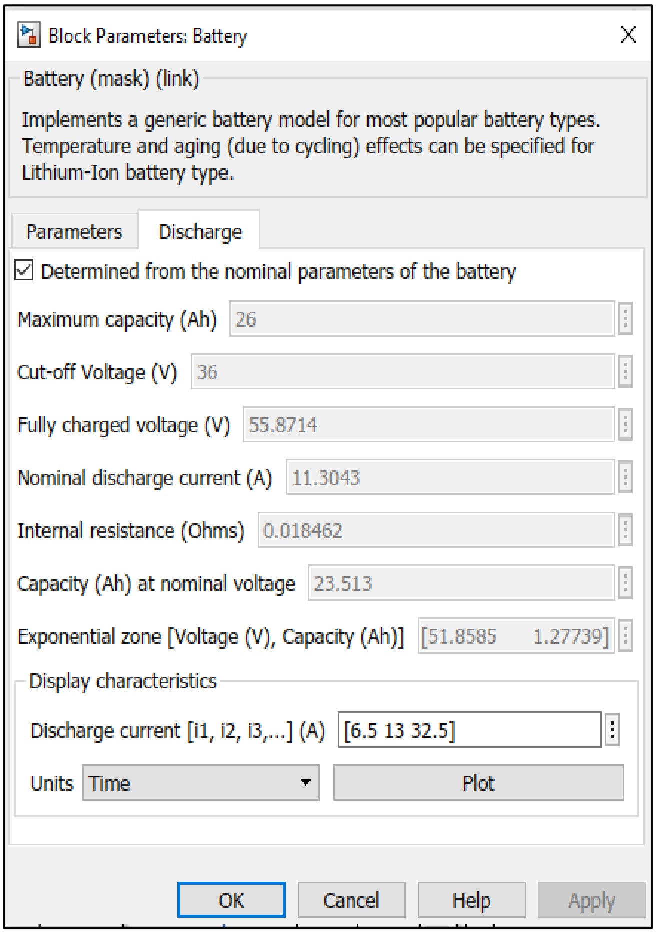

Fig 4 Battery State of Charge Parameters

The estimated discharged current is 11.3A.

Considerably, the battery run time would be determined by dividing the battery capacity in “Ah” with the load current in “A”. So we have:

Battery run time= battery capacity in Ah/ load current in A which gives 2.3hrs.

The estimated time duration for the battery to last is about 2hours 30minutes.

- *Problems and Limitation Encountered*

The powertrain of the project consists of the electric wheel hub, the battery, the motor controller, the charger and the throttle. Ideally, the motor, the ignition switch, the reverse switch, the brake pedal and the throttle pedal are connected to the motor controller which is then connected to the terminals of the battery. The throttle pedal is used to drive the wheels of the car forward or backward (reverse). Finance was the major limitation to this research project which restricted how well we could develop the prototype.

- *Below Entail the Problems we Encountered:*

All instructions (specifications) on the electric motor where in a different language (Chinese).

This problem was solved by using the Google translator application on mobile phones.

After the necessary connections were made, the wheels did not move in response to the action of the throttle pedal.

This problem was solved by using a Multimeter to test for continuity in the wires and the connection having partial contact was properly reconnected.

III. RESULTS

➢ *Simulation and Analysis Using MATLAB and SIMULINK*

Using Simulink, a block model of the powertrain of the EV is made with all the necessary parameters put in place. Thus, the result obtained from this analysis will be used to predict what will happen when the powertrain is put into its working condition and if it is safe to be developed.

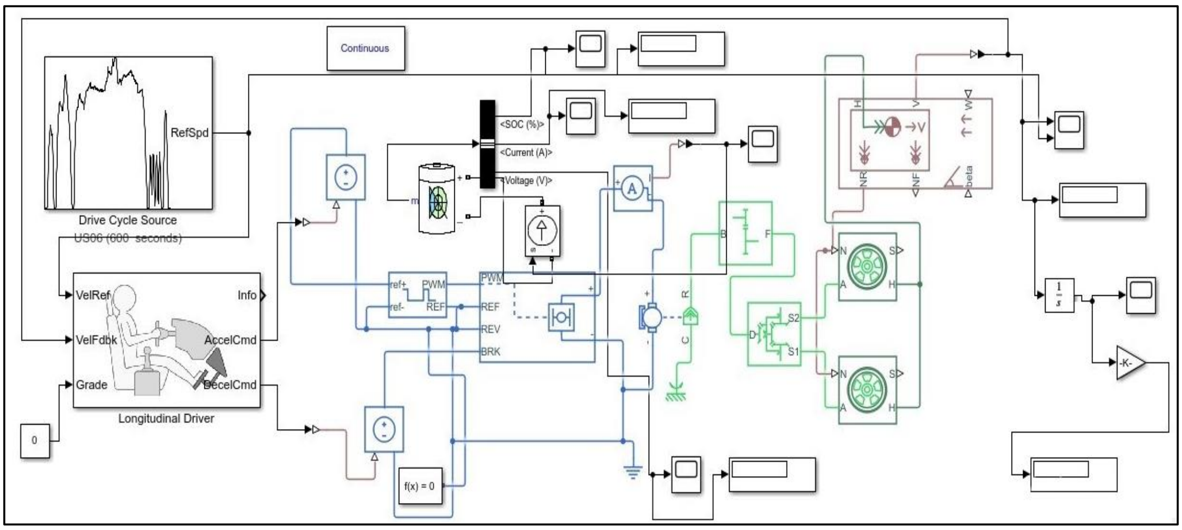

Fig 5 Model of the Electric Bike in SIMULINK

The following are the graph results for the above model simulation of the electric motorcycle.

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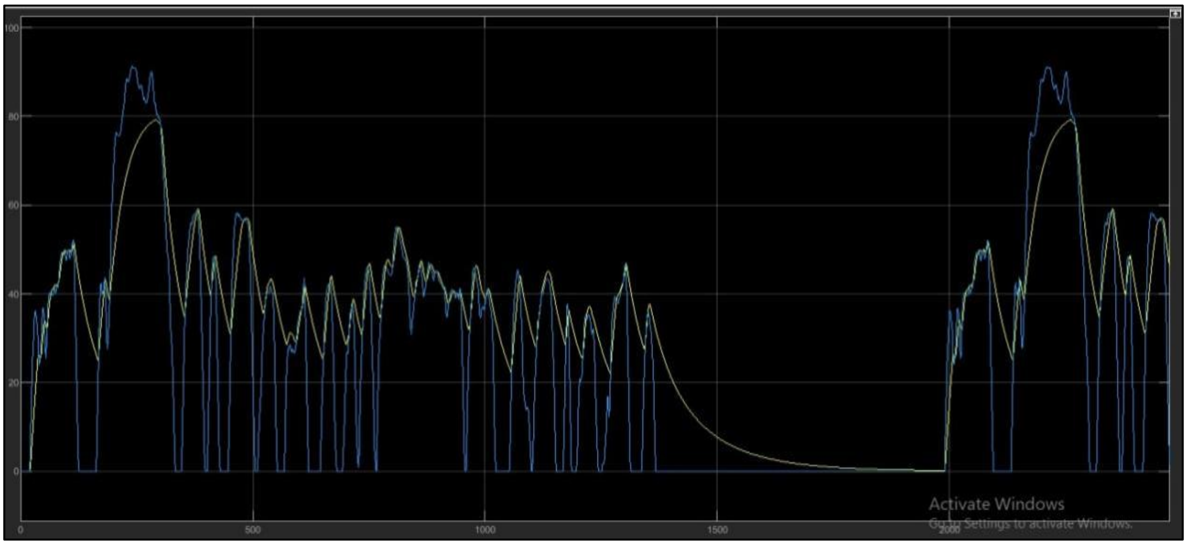

Fig 6 Drive Cycle

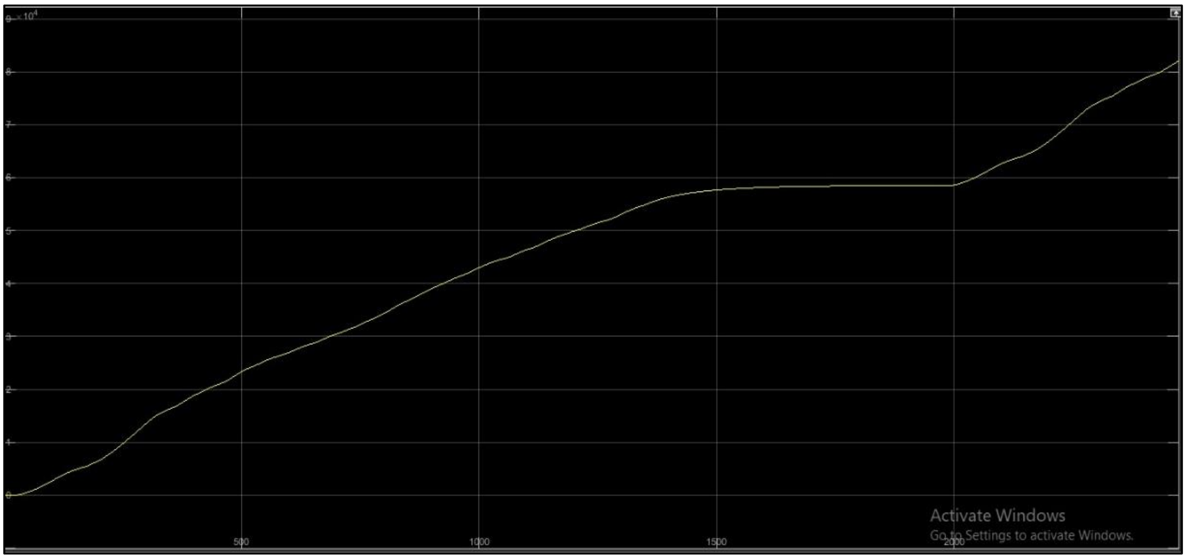

Fig 7 Distance Travelled

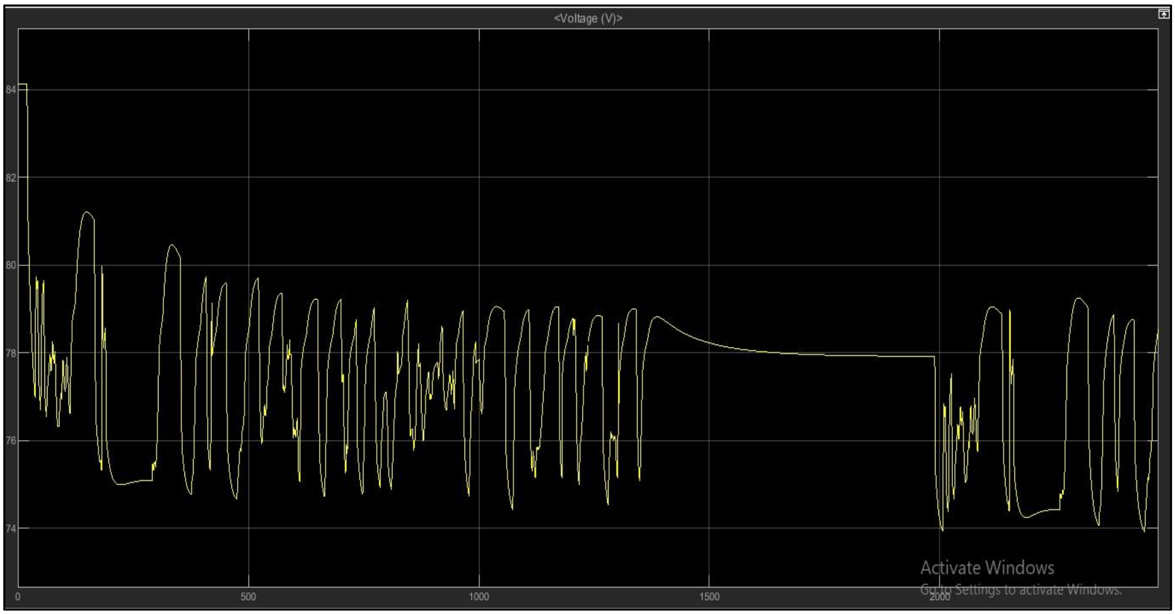

Fig 8 Battery Percentage after Simulation

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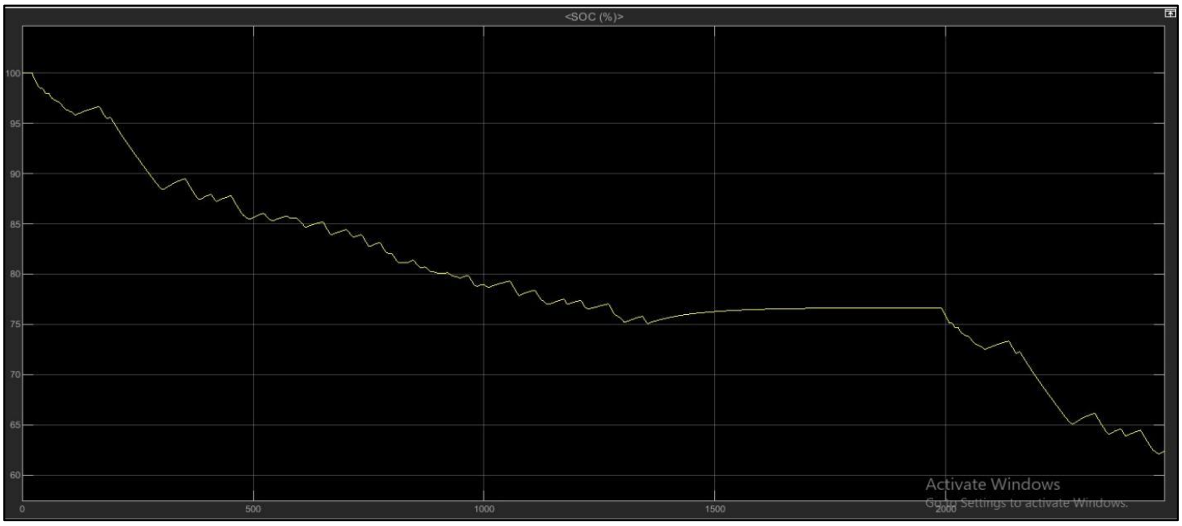

Fig 9 State of Discharge (SOC) Curve of the Battery at Various Speed

➢ *Performance Testing and Reliability Assessment*

- Drivability: having performed the drivability assessment, the degree of smoothness and steadiness of acceleration of the electric motorcycle was confirmed and no fault of stalling as a result of overload or misfiring of the motor hub was detected. It is typically motor-powered up to 42km/hr. All electrical components are functioning optimally without any noticeable faults. The seats are comfy, and the electric motor hub is noiseless during operation.

It could as well climb a sloppy region of about 45degrees conveniently without failure.

- Rigidity test: this is determined by subjecting the electric motorcycle to different loading conditions. The Stiffness introduced is the measure of how much resistance the shock absorber will provide against different loading conditions likewise the chassis. Stiffness is important since it decides how well the electric motorcycle chassis handles multi load scenarios.

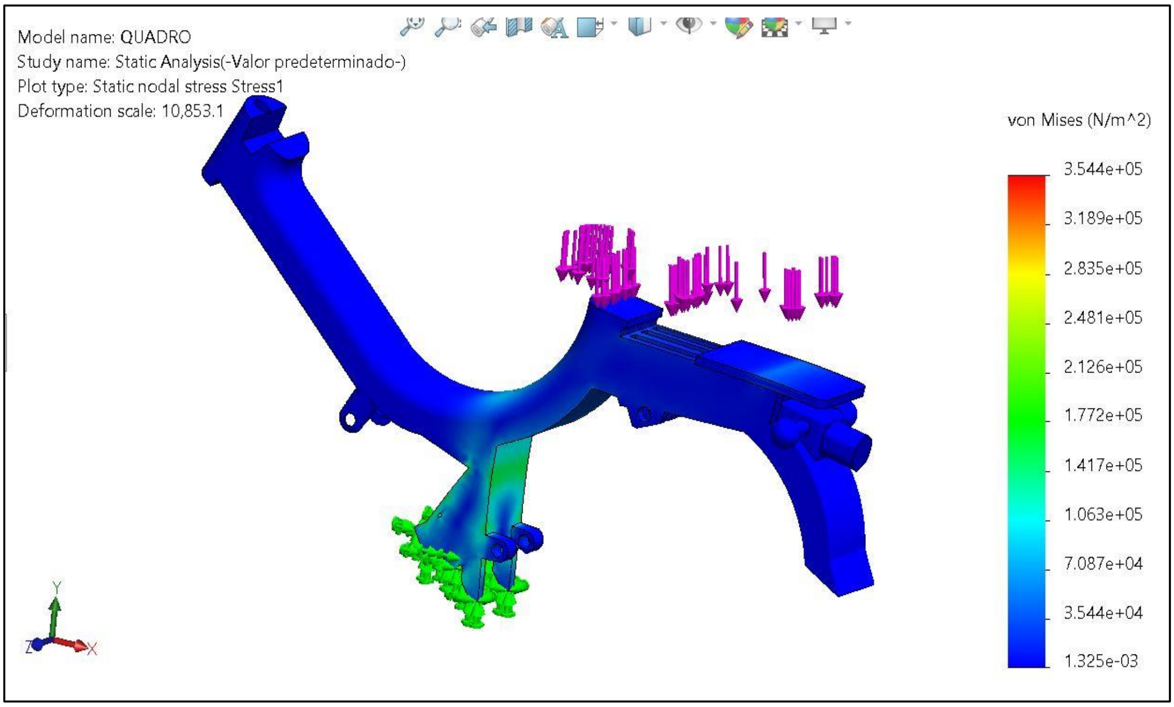

Fig 10 Load Distribution on the Electric Motorbike Chassis

- Maneuverability test: the steering stern turns at will as determined by the rider. The maximum angle of turn ranges from 45degrees to 80degrees. The clutch and the brake level are in proper position to conveniently perform the maneuverability test.

- Drift test: the degree of stability of a motor-powered motorcycle is not as efficient as compared to a high-powered or ICE motorcycle.

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Table 3 Specification DC Brushless Gearless Motor Engine

S/N	Electric motor specification	Parameters
1	Current type	Direct current (DC)
2	Gearbox	Gearless
3	Cooling system	Air cooled
4	Rated power	1500W
5	Rated Speed	70
6	Rated Efficiency	≥80%
7	Voltage	60V
8	Electric Wheel hub type	Brushless

Table 4 Parameters for Calculation

Estimated motorcycle mass	100kg
Gear Ratio	0
Brake and steering resistance	0.002
Drag coefficient	1.04
Tyre rolling resistance	0.001
Air Density	1.275
Wind coefficient resistance	1
Motorcycle efficiency	0.80

Fig 11 Conversion Process for the IC Engine Bike

Fig 12 Picture of the Converted Bike (Prototype)

Fig 13 The Electric Bike Prototype being Tested by a Rider

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➢ *Bill of Engineering Measurement and Evaluation for the Powertrain*

Table 5 Bill of Engineering Management and Evaluation

S/N	DESCRIPTION	QUANTITY	RATE (NGN)	AMOUNT (NGN)
1	Electric Motor hub	1	91,000	91,000
2	Battery charger	1	15000	15000
3	Motor controller	1	38000	38000
4	Battery	1	135,000	135,000
5	Motorcycle	1	420,000	420,000
	MISCELLANEOUS (TRANSPORTATION AND CLEARANCE)	160,000		
	TOTAL	859,000		

Fig 14 Diagram of the Electric Motorcycle

* *Performance Testing of the Powertrain (No Load Test)*

The electric vehicle was observed when running for three hours under no load in order to identify the maximum travel capacity of the battery. And the below parameters and calculations where obtained;

Speed- 4m/s (14km/hr.)

Time duration- 3 hours

Voltage of the battery- 60-40 V (due to the voltage protection system of the motor controller.)

Distance cover = velocity $\times$ time taken

Distance = 14 $\times$ 3 = 42 km

From the above calculations, we have that the distance traveled by the electric vehicle on NO-LOAD is 42km under 3 hours at a speed of 14km/hr. An average ICE vehicle moving at an economic speed has an average figure of 10km/hr. it can be obtained that the electric vehicle has an efficiency of about 12km/hr. under minimal load and with this, it can be stated that the electric vehicle has a higher efficiency than an ICE vehicle.

IV. CONCLUSION

To achieve the aim and objectives of the project, the team has worked diligently on the construction of the prototype electric bike. The up-to-date program on the powertrain is at 100% completion, the powertrain was built based on a stable design which is light in weight compared to other ICE design. The powertrain is safe enough, able to transmit the required torque for the necessary weight of the vehicle, it reduces/ eliminates carbon emission and it also possesses an efficiency above 80% which is very good when compared to that of an ICE engine. At this point the bike is mobile, all aims of this project has been achieved. This project indicates that the gap between a zero emission and the transportation sector in Nigeria can be bridged at a relatively low cost and with localized assembly. This bike is also efficient since it has fewer moving parts, and it utilizes the energy supplied to it from charging. This is a scalable project and it can serve as a model for local vehicle manufacturers and institutions looking to further this topic.

In summary: Electric bikes can be designed and assembled cost-effectively in Nigeria. Their adoption will promote cleaner energy within Nigeria's transportation sector. Compared to internal combustion engine counterparts, electric bikes offer superior efficiency. With continued research and development, this project shows strong potential for economic viability.

Due to financial constraints and national holidays in china during fabrication period, ordered components took longer time than expected. Also, installation of minor accessories such as side mirrors, mechanical shutdown switch, front and rear lights and overall bike ergonomics would not be possible due to financial constraints.

In other to improve the efficiency of the Electric bike, a battery with higher voltage and motor with higher KV rating should be used. This will help in improving the overall drive efficiency of the bike and as well as its overall efficiency.

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