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Simulation of Electric Bike using Simulink

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Abstract -Modern world demands the high technology which can solve the current issues and future problems. Now-a-days Fossil fuel shortage is the main problem. Considering current rate of usage of fossil fuels will let its life up to next five decades only. Because of undesirable change in climate is the red indication for not to use more fossil fuel any more. Best alternative for the automobile fuels to provide the mobility & transportation to peoples is sustainable electrical bike. Future e-bike is the best technical application as a visionary solution for the better world, upcoming generation and environment. E-bike comprises the features like high mobility efficiency, compact, electrically powered, comfortable riding experience, light weight vehicle. E-bike is the most versatile current and future vehicle considering its advantages.
Keywords: Electric Bike, Electric Energy, Controller, Motor, Battery.

I. INTRODUCTION

Ground transportation is a notoriously difficult service to provide directly through electricity, a fact evidenced by the preponderance of liquid and gaseous fuels used in most modesof transportation. There is, however, increasing pressure to shift away from these fuels due to their associated greenhouse gas (GHG) emissions which is driving new innovations. Some modes of transport are already served by grid-tied electricity, such as trolley busses and some passenger train lines. None the less, it has been the evolution of hybrid drivetrains pursued to increase the efficiency of conventional IC engine vehicles together with recent developments in battery technology that has enabled plug-in vehicles to become a realistic option. The program of research outlined in this paper is aimed at examining the prospects for GHG reductions through drivetrain electrification across a range of vehicle types. This line of research finds particular motivation in BC where transportation is the largest single GHG emissions sector (37.9%) and onroad transportation 23.7% [1]; nationally in Canada all transportation is 24.2% of total GHG emissions [2]. The analysis will include grid integration of the vehicles, in particular demand response approaches, in order to capture interaction effects that must be considered apart from the vehicles themselves.

The follow sections highlight the avenues of research being pursued. The first area focuses on the vehicles themselves, specifically on battery drive train options relative to fuel cells and applications across personal and fleet vehicles in addition to electric bikes. The next section describes the work being carried out to better assess the grid-integration of electric vehicles. This includes models adapted to considering the stochasticity of generation and loads, as well as the reality of interconnected, transnational grid operations that mean BC cannot be studied in isolation. Load control through demand response (DR) techniques is also discussed in order to better handle and even synergistically exploit vehicle charging to

integrate grid-scale renewables as well as distributed solar generation.Main reason to identify the need of finding and modifying E-Bike is to overcome the issue of the pollution because of vehicles inmetro towns & urban zones is swelling uninterruptedly. Considering the all class of society it is not reasonable for all to purchase (scooters, mopeds or motorcycles). So, combining both issues, environmental progress supporting and economical affordable alternative would be the best solution. Typical parts of E-bike (Electric Bike) are Brushless DC Motor (Induction Motor), Throttle (Accelerator), Battery Storage (48 V), Chain Drive, Frame and other common bike parts. The electric bike is a new form of private transport has led to a new approach to mobility, especially in cities both for countries with large populations and for countries that are concerned about the environment. The research on the electric bike is relatively new, but today, nobody clearly knows where the efforts are being focused, nor what the main points of interest of the scientific community are. The objective of this manuscript is to detect how the worldwide research of the electric bike is being developed and especially around which scientific domains it is clustered. Finally, the main trends in this field can be identified.

The batteries of the electric bike can be recharged by connecting them to a plug. In addition, a typical electric bike needs 6–8 h to charge the battery and has a range of travel of 35 to 50 km at a speed of about 35 km/h (depending on rider weight). This means that, with a single battery charge, it would be enough to go to work, visit friends, and return home on a normal day, since statistics show that about half of the trips and procedures of a normal urban person are carried out within a distance of 50 km from his/her house, therefore within the reach of these bikes. Because of this need more development in the era of electric vehicle as per the distance concern. From an environmental point of view, for petrol car consumption in urban areas, the emissions are: HC (Hydrocarbons) 3.57 g/km, CO 3.15 g/km, CO2 1.82 g/km, and NOx 2.29 g/km. Therefore, the electric bike, as an alternative means of transport to the car, shows that for every 100 km an average of 8.5 L of gasoline is saved, and this pollution would be avoided. The electrically assisted bikes are normally powered by rechargeable battery and their driving performance is influenced by battery capacity, motor power, road types, operation weight, control, and, particularly, by the management of the assisted power.

The increase of pollution and congestion due to progressive urbanization is transforming city mobility. Among new mobility trends bike sharing has turned out to be extremely

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successful [1]. Bikes have the advantage of being healthy, eco-friendly, often the fastest among means of transportation in congested cities, and cost-effective. However, the cycling effort can discourage the service usage or even limit the service accessibility. Electric Powered Assisted Cycles (EPACs) are bicycles powered with electric energy, they use zero-emission technology to decrease the cycling effort.This makes them a good candidate for urban mobility.

II. BLOCK DIAGRAM OF ELECTRIC BIKE

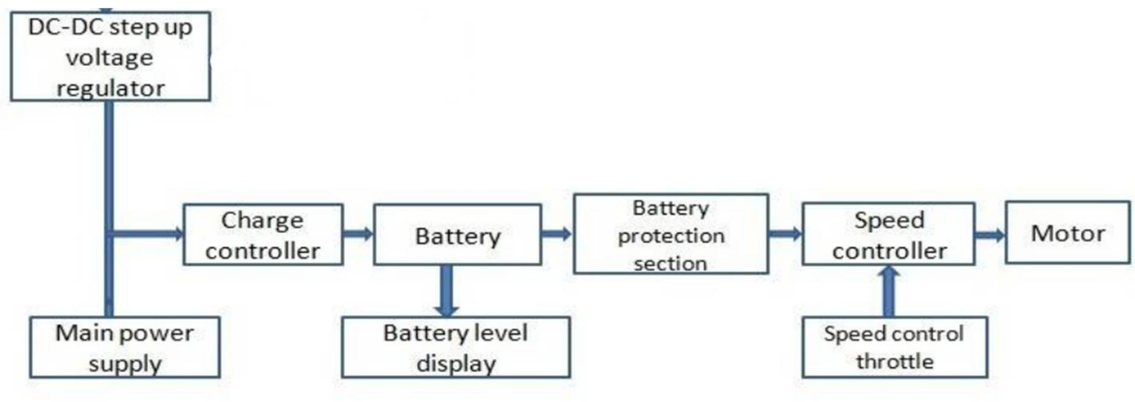

Fig 1: Block diagram of electric bike

A boost converter is a step-up Chopper. It converts power from variable DC to fixed DC. It steps up's voltage from input to load. It is a class of switched mode power supply (SMPS). Step up chopper is a static device whose average output voltage is greater than input voltage.

A. DC-DC Step Up Voltage Regulator
A boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load).

B. Charge Controller
A charge controller, charge regulator or battery regulator limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may protect against overvoltage, which can reduce battery performance or lifespan and may pose a safety risk. It may also prevent completely draining ("deep discharging") a battery, or perform controlled discharges, depending on the battery technology, to protect battery life. The terms "charge controller" or "charge regulator" may refer to either a stand-alone device, or to control circuitry integrated within a battery pack, battery-powered device, or battery charger

C. Battery
A battery is a power source consisting of one or more electrochemical cells with external connections for powering electrical devices such as flashlights, mobile phones, and electric cars. When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode. The terminal marked negative is the source of electrons that will flow through an external electric circuit to the positive terminal. When a battery is connected to an external electric load, a redox reaction converts high-energy reactants to lower-energy products, and the free-energy difference is delivered to the external circuit as electrical energy. Historically the term "battery" specifically referred to a device composed of multiple cells, however the usage has evolved to include devices composed of a single cell.

D. Battery Protection Section
The high power density of Lithium-Ion batteries has made them very popular. However, the unstable behavior of Lithium-Ion cells under critical conditions requires them to be handled with care. That means a Battery Management System (BMS) is needed to monitor battery state and ensure the safety of operation. BMS is typically equipped with an electronic switch that disconnects the battery from charger or load under critical conditions that can lead to dangerous reactions. A **battery protection** unit (BPU) prevents possible damages to the battery cells and the failure of the battery.

E. Speed Controller
An electronic speed control (ESC) is an electronic circuit that controls and regulates the speed of an electric motor. It may also provide reversing of the motor and dynamic braking. Miniature electronic speed controls are used in electrically powered radio controlled models. Full-size electric vehicles also have systems to control the speed of their drive motors.

F. Motor
A DC motor is any of a class of rotary electrical motors that converts direct current electrical energy into mechanical energy. The most common types rely on the forces produced by magnetic fields. Nearly all types of DC motors have some internal

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mechanism, either electromechanical or electronic, to periodically change the direction of current in part of the motor.

G. Speed Control Throttle

An engine's power can be increased or decreased by the restriction of inlet gases (by the use of a throttle), but usually decreased. The term throttle has come to refer, informally, to any mechanism by which the power or speed of an engine is regulated, such as a car's accelerator pedal. What is often termed a throttle (in an aviation context) is also called a thrust lever, particularly for jet engine powered aircraft. For a steam locomotive, the valve which controls the steam is known as the regulator.

H. Battery Level Display

It displays the remaining amount of battery in the electric bike with respect to time. It also shows the range of the electric bike.

III. WORKING OF ELECTRIC BIKE

The Electric bike is a bike which is driven with the help of battery which is coupled to electricmotor.

A. Main Principle

It works on the principle that the electromotive force of an A.C. motor whichreceives electrical energy stored in D.C. battery is converted with the help of D.C. to A.C.converter

B. Working Medium

Here for the motivation of prime mover the chemical reaction takes place from which an energizing current is evolved which is responsible for the working. The working medium is sulphuric acid which is separated into columns of H ions and negative SO4 ion when mixed with water. If the poles of the cell are connected by a load, the flow of the electrons is from negative to positive. A bivalent positive lead is produced from neutral lead whencombined with bivalent negative of SO4 group to form lead sulphate. This results due to scarcity of electrons at negative pole. Through the electron supply a bivalent positive lead is produced at positive pole from quadrivalent positive lead. A combination of SO4 comes into existence thereby ruling the combination of O2 which leads to formation of PbSO4. The atoms of oxygen and hydrogen from electrolyte are released together to form water thereby decreasing the density of battery acid.

C. Operation

In this a DC waveform which is obtained id made sinusoidal due to operational transistorized D.C. to A.C. amplifying circuit by switching the electric energy in the form of electric current which flows from battery to D.C. to A.C. converter circuit. By using amplifier circuit the small A.C. current is amplified again. In order to drive the circuit through the condenser, this amplified current is fed to the stator winding of the A.C. motor. The condenser
which is used acts as a storage of electric energy and delivers at the time of requirement. The sprocket wheel installed on motor shaft is driven by the motive power of the electric energy. The rear sprocket wheel is being rotated by the chain drive mechanism on which the other two remaining sprocket wheels are installed. The wheel is driven by the rear wheel installed on the rear sprocket. Thus the electric bike is mobilized by using electric power.

IV. CHARGING SYSTEM OF ELECTRIIC BIKE

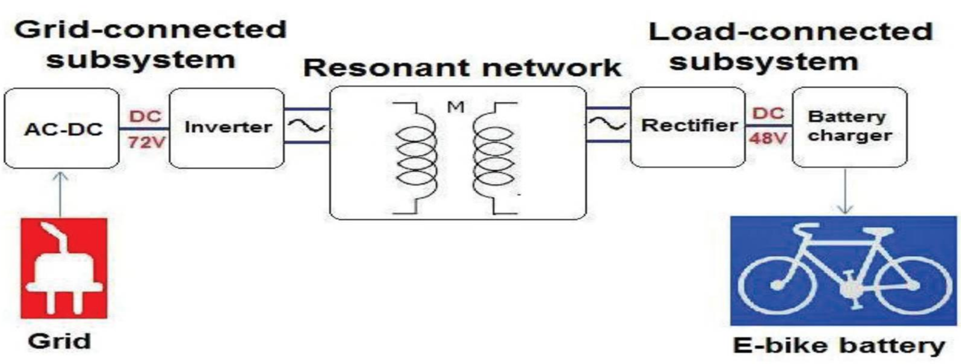

Fig 2: Electric Bike Charging System

Fig shows a block diagram of the proposed recharging system, compliant with an E-bike battery. From the left to the right, the following parts are shown: the grid-connected subsystem, also referred to as power transmitter; the resonant network, including

a magnetic coupling structure; the load-connected subsystem, also referenced as power receiver, which supplies the final rechargeable battery. Nowadays LiFePO4 batteries are typically employed for E-bike supply. The proposed recharge system complies with a 36V 10Ah LiFePO4 battery, whose dimensions are 64*148*365mm. The battery voltage lies in the range 30V□43.8V. The designed system envisions an about 100W recharge.The grid-connected subsystem includes an AC-DC stage,

which converts the grid AC low frequency voltageinto a 72V DC voltage, and an inverter, which converts the DC voltage into a high frequency AC signal. Due to the magnetic coupling inside the resonant network, a wireless power transfer occurs from power transmitter to power receiver, consisting of this AC signal flowing towards the load-connected subsystem.
The power receiver includes: an active rectifier, which efficiently converts the AC signal into a 48V DC bus level; a battery charger, which controls the flow of charge from rectifier to battery; the E-bike LiFePO4 battery. The following design procedure has been undertaken. According to the envisioned spatial constraints referring to an E-bike battery wireless recharge, the magnetic coupling structure has been selected and analyzed through magnetic simulation software. From the magnetic simulator analysis, inductive and resistive parameters values have been obtained and consequently included in the circuit simulation model of the whole charging equipment. Based on the selected coil length, wire section and material, skin effect losses versus operating frequency have been modeled too. In order to obtain the nominal 48V rectifier output voltage together with a high coupling efficiency value, a fixed and resonant operating frequency control has been implemented. Power load regulation is achieved by varying the duty-cycle of the inverter square wave

A. Load Connected Sub-System

In the proposed system simulation model, the battery charger and the rechargeable battery are considered as the actual load, so that the rectifier is the main power receiver part which is widely described in this paper. In order to evaluate the system efficiency, the rectifier
input resistance shall be evaluated. At the resonant frequency, the equivalent load resistance (*Rr*) of the resonant network is given by:

$$R_r = (8/\pi^2) \text{ x } R_L \qquad (1)$$

where *RL* is the actual load resistance as seen by the rectifier. Considering a 48V DC bus level and a 2A load current, *RL* value is equal to 24. Therefore, according to
(1), *Rr* is given by (2):

$$R_r = (8/\pi^2) \text{ x } 24 = 19.4\Omega$$

An active full-wave rectifier bridge has been preferred to the conventional four-diode configuration, in order to enhance power conversion efficiency. Indeed, since each MOSFET features a very low conduction resistance, power losses are less than using the traditional passive full-wave rectifier, even in the most efficient Schottky diode case

V. COMPONENTS OF ELECTRIC BIKE

The Electric bike consists of following components viz, DC motor, Frame, Platform, Battery,Drive etc.

A. DC Motor

The motor is having 250 watt. Capacity with maximum 2100 rpm. Itsspecifications are as follows:
Current Rating: 7.5amp
Voltage Rating: 48 Volts
Cooling: Air – cooled
Bearing: Single row ball

Fig 3: DC motor

B. Frame

The Frame is made up of M.S. along with some additional light weight components. The frame is designed to sustain the weight of the person driving the unit, the weight of load to be conveyed and also to hold the accessories like motor. Also it should be

design to bear and overcome the stresses which may arise able to due to different driving and braking torques and impact loading across the obstacles. It is drilled and tapped enough to hold the support plates.

C. Platform

The Platform is designed with robust base so that it can hold the load along with the weight of the driving person uniformly. It is fabricated from Mild Steel at a specific angle in cross section and welded with a sheet of metal of specific thickness. The platform's alignment is kept horizontal irrespective whether it is loaded or unloaded and this is directly bolted and welded to the frame.

D. Battery

The battery also acts as a condenser in a way that it stores the electric energy produced by the generator due to electrochemical transformation and supply it on demand.Battery is also known as an accumulator of electric charge. This happens usually while starting the system.

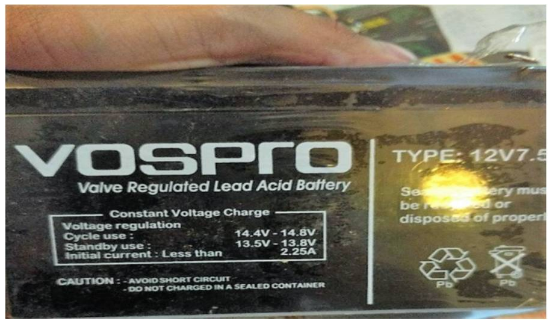

Fig 4: Battery

E. Chain Drive

A Chain is an array of links held together with each other with the help of steel pins. This type of arrangement makes a chain more enduring, long lasting and better way of transmitting rotary motion from one gear to another.The major advantage of chain drive over traditional gear is that, the chain drive can transmit rotary motion with the help of two gears and a chain over a distance whereas in traditional manygears must be arranged in a mesh in order to transmit motion.

Fig 5: Chain Drive

F. Braking System

For the braking system it is convenient to use braking system used in band brake system which consist of spring loaded friction-shoe mechanism, which is driven with the help of hand lever.

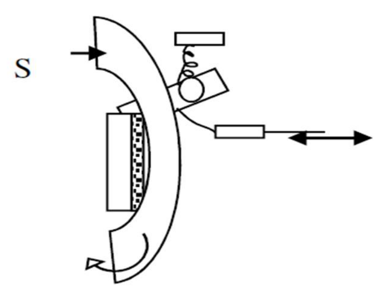

Fig 6: Braking System

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G. Sprockets

The chain with engaging with the sprocket converts rotational power in to rotary power and vice versa. The sprocket which looks like a gear may differ in three aspects.

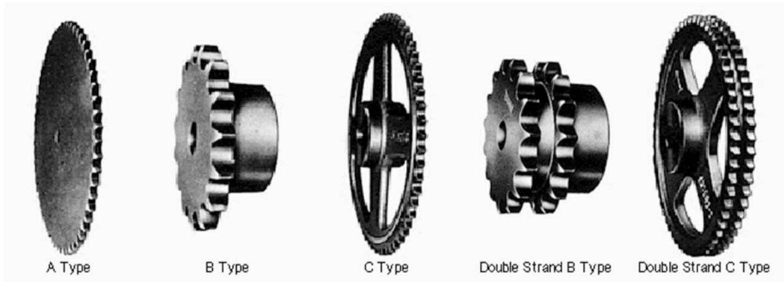

Fig 7: Types Of Sprockets

- Sprockets have many engaging teeth but gears have only one or two.
- The teeth of a gear touch and slip against each other but there is basically no slippage in case of sprocket
- The shape of the teeth are different in gears and sprockets.

VI. DESIGN OF ELECTRIC BIKE

Here we have used permanent magnet self-generating motor with 250 watt power and 2100rpm. The motor runs on 48volts and 7.5amps power source. This motor can reach a peak current during starting equal to 15 amps. (Barve, Design and Development of Solar Hybrid Bicycle, March 2016)

P = 2 x 3.14 x N x T /60
250 = 2 x 3.14 x 2100 x T /60
T = 1.13 N m = 1136 N-mm
Reduction in chain drive
R chain = 66/11 = 6:1
Torque at wheel shaft = T x R chain = 1136 x 6 = 6820 N mm = 350 rpm

A. Design Of Shaft

1) *Bending:* The force which develops across a specific cross section of the shaft, it generates stress at that point of cross section that are subjected to maximum loading. This internal or resisting moment gives rise to the stress called as bending stresses
2) *Torsion:* When the shaft which is twisted by the couple such that the axis of that shaft and the axis of the couple harmonize, that shaft is subjected to pure torsion and the stresses generated at the point of cross section is torsion or shear stresses.
3) *Combined Bending and Torsion:* In actual practice the shaft is subjected to combination ofthe above two types of stresses i.e. bending and torsion. Thebending stresses may occur dueany one of the following reasons:
   - Weight of belt
   - Pull of belts
   - Eccentric Mounting of shafts/gears
   - Misalignment of shafts/gears

On contrary, the torsional movement occurs due to direct or indirect twisting of the shaft. Hence at any given point on cross-section of the shaft, the shaft is subjected to both bending and torsional stresses simultaneously. Following stresses are taken in consideration while designing the shaft:

Shaft design

T = 36000 N mm
T = 3.14 / 16 x σs x d3
Fs allowable = 80 N/mm2
6820 =3.14 x σs x d3/16
σs = 34.73 N/mm2
Material = C 45 (mild steel)
σ ut = 320 N/mm2 ------------ PSG design data book.
factor of safety = 2
σt = σb = σ ut/ fos
= 320/2
= 160 N/mm2
σs = 0.5 σt

= 0.5 x 160

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= 80 N/mm2
σs is less then allowable so our shaft design is safe.

4) Design of Chain and Sprocket for Electric Bike: We know,
TRANSMISSION RATIO = Z2 / Z1 = 66/11 = 6
For the above transmission ratio number of teeth on pinion and the number of teeth sprocket is in the range of 21 to 10, so we have to select number of teeth on pinion sprocket as 11 teeth. So, Z1 = 11 teeth

5) Selection of Pitch of Sprocket:
The pitch is decided on the basis of RPM of sprocket.
RPM of pinion sprocket is variable in normal condition it is = 2100 rpm
For this rpm value we select pitch of sprocket as 6.35mm from table.
P = 6.35mm

Calculation of minimum centre distance between sprockets:
THE TRANSMISSION RATIO = Z2 / Z1 = 66/11 = 6 which is less than 7
Dia. of small sprocket,
Periphery = π × dia. Of sprocket
11 × 6.25 = π × D
D = 11 × 6.25 / π
D = 21.8 mm
Dia. of sprocket,
Periphery = π × dia. Of sprocket
66 × 6.25 = π × D
D = 66 × 6.25/ π
D = 131.3 mm
So from table, referred from PSG Design Data book
The minimum centre distance between the two sprocket = C' + (80 to 150 mm)
Where C' = Dc1 + Dc2
2
C'= 131.3 + 21.8
2
C' = 76.5 mm
MINIMUM CENTER DISTANCE = 76.5 + (30 to 150 mm) MINIMUM CENTER DISTANCE = 170 mm

Calculation of values of constants K1 K2 K3 K4 K5 K6 – (with help of PSG Design Data)
Load factor K1 = 1.25 (Load with mild shock)
Distance regulation factor K2 =1.25(Fixed center distance)
Center distance of sprocket factor K3 =0.8
Factor for position of sprocket K4 = 1
Lubrication factor K5 = 1.5 (periodic)
Rating factor K6 = 1.0 (single shift)

Calculation of value of factor of safety
For pitch = 6.35 & speed of rotation of small sprocket = 2100 rpm
Factor of Safety for this drive = 8.55
Calculation of Allowable Bearing Stress:
For pitch = 6.35 & speed of rotation of small sprocket = 2100 rpm
Allowable Bearing stress in the system = 2.87kg / cm2
=2.87 * 981/100 =28 N /mm2

Calculating Maximum Tension on Chain
Maximum torque on shaft = Tmax = T2 = 6820 N-mm
Where,
T1 = Tension in tight side
T2 = Tension in slack side
O1, O2 = center distance between two shaft
Sin μ = R1 - R2
O1O2
Sin μ = 65.65 - 10.9
170

Sin μ = 0.33

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μ = 18.78
TO FIND q
q = (180 –2μ) X 3.14/180
q = (180 –2*18.78) X 3.14/180
q = 2.48 rad
According to this relation,
T1/T2 = eμq
T1/T2 = e0.35 x 2.48
T1 = 2.38T2
We have,
T = (T1 – T2) X R
6820 = (2.38 T2 – T2) X 65.65
T2 = 75.27 N
T1 = 2.38 X 75.27
T1 = 179.16 N
So tension in tight side = 179.16 N
We know,
Stress = force / area x 2
Stress induced = 179.16/ (3.14 * 32 / 4) x 2
Stress induced = 12.67 N /mm2
As induced stress is less than allowable stress =28N /mm2design of sprocket is safe.

VII. BRAKE SYSTEM

Stopping the vehicle from 400 mph is nearly as difficult as accelerating it to this speed. The primary means for stopping the vehicle from high speed is parachutes. Although the vehicle carries multiple parachutes, parachute failures sometimes occur and can lead to a crash. Therefore, the BB3 will have a redundant mechanical braking system capable of stopping the vehicle from full speed without parachutes. This could not be achieved with conventional automotive brakes. A custom braking system was designed to accomplishthis task utilising carbon disks. The carbon disks used in the system are from an Embraer 145 regional jet. The BB2 utilised a similar system; however, owing to the increased vehicle speed, an all new system had to be developed for the new vehicle. This system functions more like a clutch rather than a conventional brake disk. There are four rotors and five stators per each brake unit. The rotors and stators are stacked together in an alternating fashion and compressed by six hydraulic pistons. A model of the system is shown in Figure

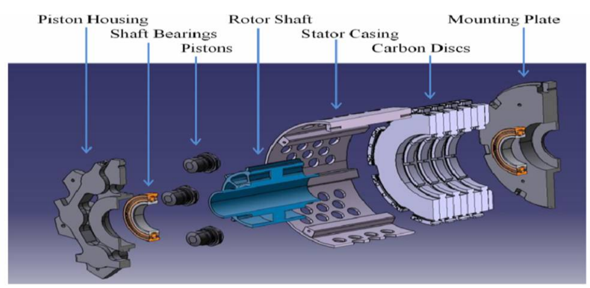

Fig 8: Mechanical Braking System Model

The friction braking system is for use primarily at low speeds under 100 mph (44.7 m/s). In the event of a complete failure of the parachute system, the frictional braking system in conjunction with the vehicle drag and rolling resistance must be able to stop the vehicle within 5.5 miles. Although all safety systems are being designed for safe operation up to 400 mph, it is impractical and unnecessary to size the friction braking system for this speed. In the event of a parachute failure at high speeds, the vehicle will be able to coast until the vehicle reaches 350 mph and then apply the frictional brake system. In this way, the amount of energy dissipated by the air resistance is maximized.

A. Suspension System

The Bonneville salt flats have been selected as the test site for the BB3 specifically for their vast expanse of flat land. However, the salt flats are still a natural granular surface and are not perfectly smooth. To maximise traction, it is desirable to maintain wheelcontact with the ground. The suspension system facilitates maintaining wheel contact with the ground and absorbs surface irregularities that would transfer significant shock load to the chassis and driver. The BB3 suspension system is designed around the premise of high-speed stability without compromise for turning dynamics as the vehicle does not perform high-speed cornering. The BB3 will have a fully independent double A-arm suspension similar to that of the BB2. The suspension has equal length A-arms at the top and bottom to eliminate camber gain. The suspension has no kingpin inclination to eliminate weight jacking and camber gain while turning. The upper and lower ball joints are positioned at the wheel centreline to eliminate scrub radius. The CV joints are positioned within the wheel centreline to eliminate torque steer. The suspension system is mounted on the gearbox to form a complete drive unit. To improve serviceability and reduce the number of spare parts required to keep on hand, the suspension is identical at the front and rear with the exception of the steering linkages. The suspension model is shown in Figure.

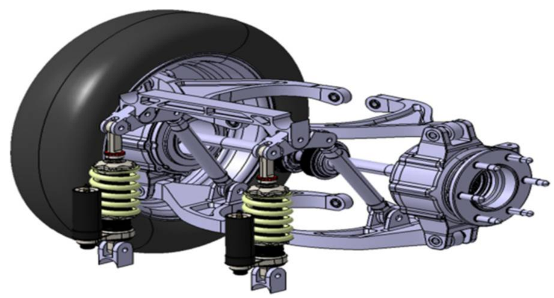

Fig 9: Suspension System braking Model

1) *Advantages of Suspension System Model:*
- Easy to commute with low fatigue.
- Less maintenance cost.
- Normal Drag/Pedal is possible when power is not in use.
- Deployable batteries – can be taken inside house.
- Cost of the unit is very low.
- Easy to carry since it is portable.
- Less energy consumed.
- High efficiency can be obtained if inverter is used.
- If using solar panel, free utilization of energy can be done.

2) *Disadvantages of Suspension System Model:*
- High intensity of wind load.
- High centre of gravity.
- Cannot tolerate drastic changes in environment.
- Needs Periodic Monitoring

Output of MPP is in DC form. Initially it is obtained between 0 to 100 KW and it is fluctuating. The output is sticked to a constant value of 100kw with some small deviations in it this is the output of the MPP.

VIII. SIMULATION

A. *Simulation Diagram*

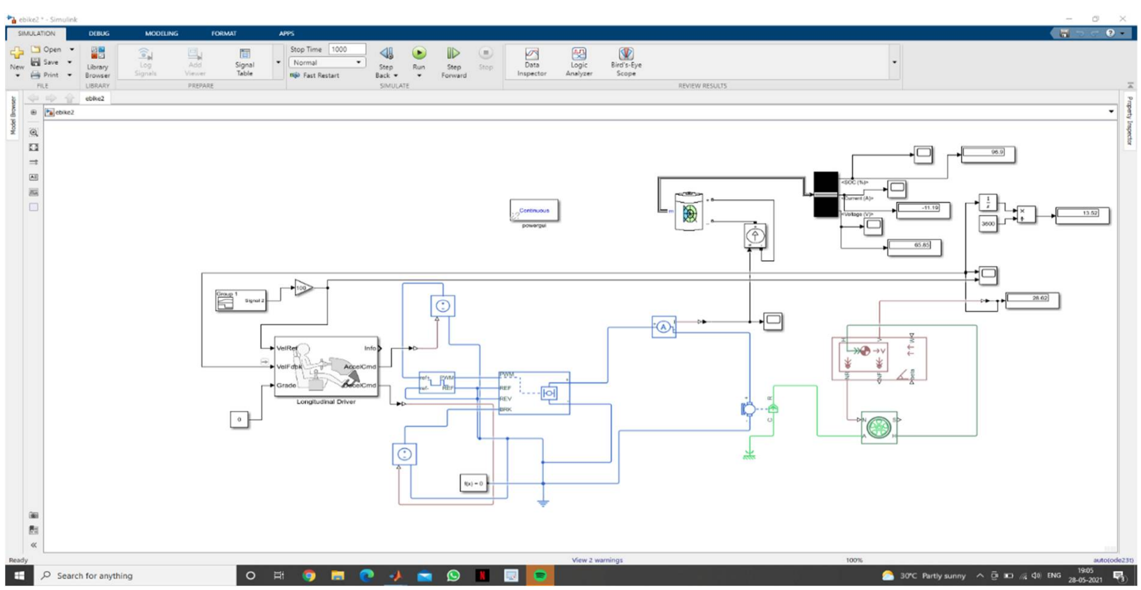

Fig 10: Simulation Diagram

B. Current of DC Motor

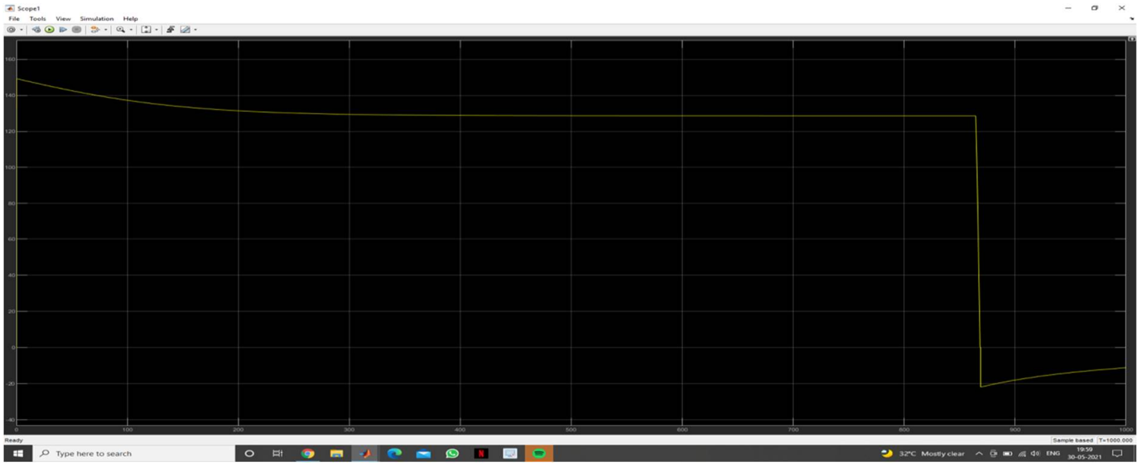

Fig 11: Current of DC Motor

C. State of Charge %

Fig 12: State Of Charge %

D. Battery Current

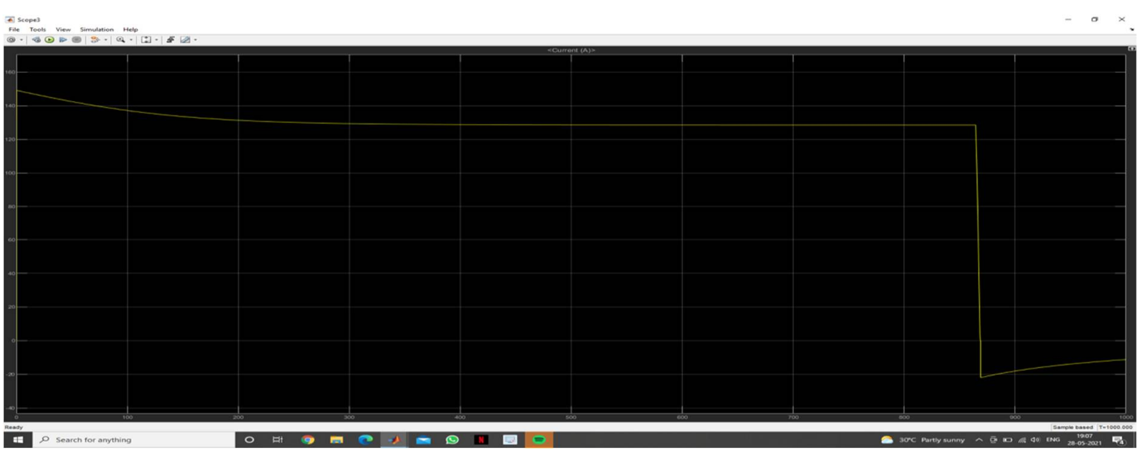

Fig 13: Battery Current

E. Battery Voltage

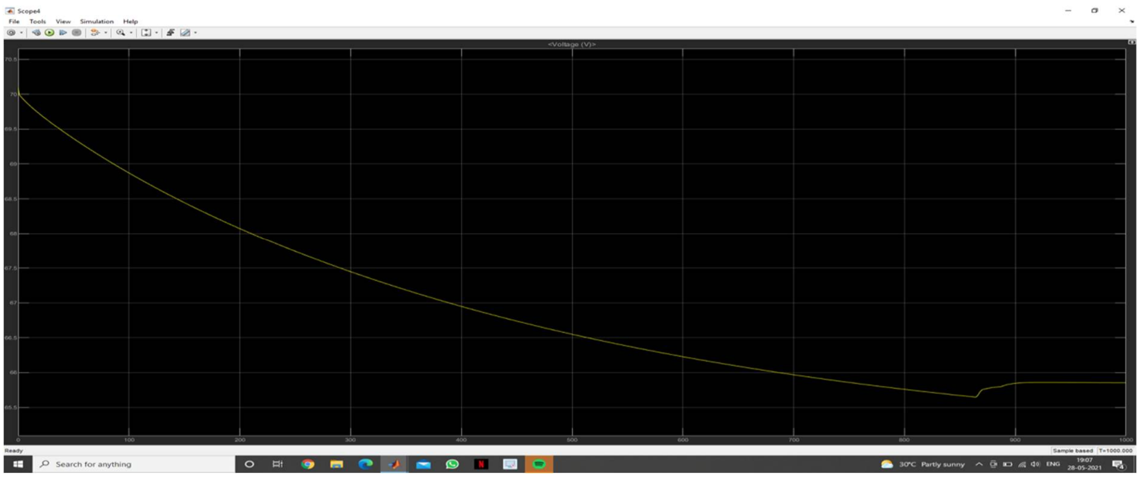

Fig: 14 Battery Voltage

F. Average Velocity

Fig 15: Average Velocity

IX. CONCLUSION

From the above study and we design and developed the new model of electric bike. With the defined power supply and calculation made for use of battery, sprocket design and motor is the way towards betterment of performance, comfortable, compact, high speed and efficient can be achieved. In this study had provided several results and guidelines that can assist for improvements in the performance of electric bikes. Future developments in electric bike will concern the design of several control strategies like battery, motor and controller by means of hardware in the loop procedure.

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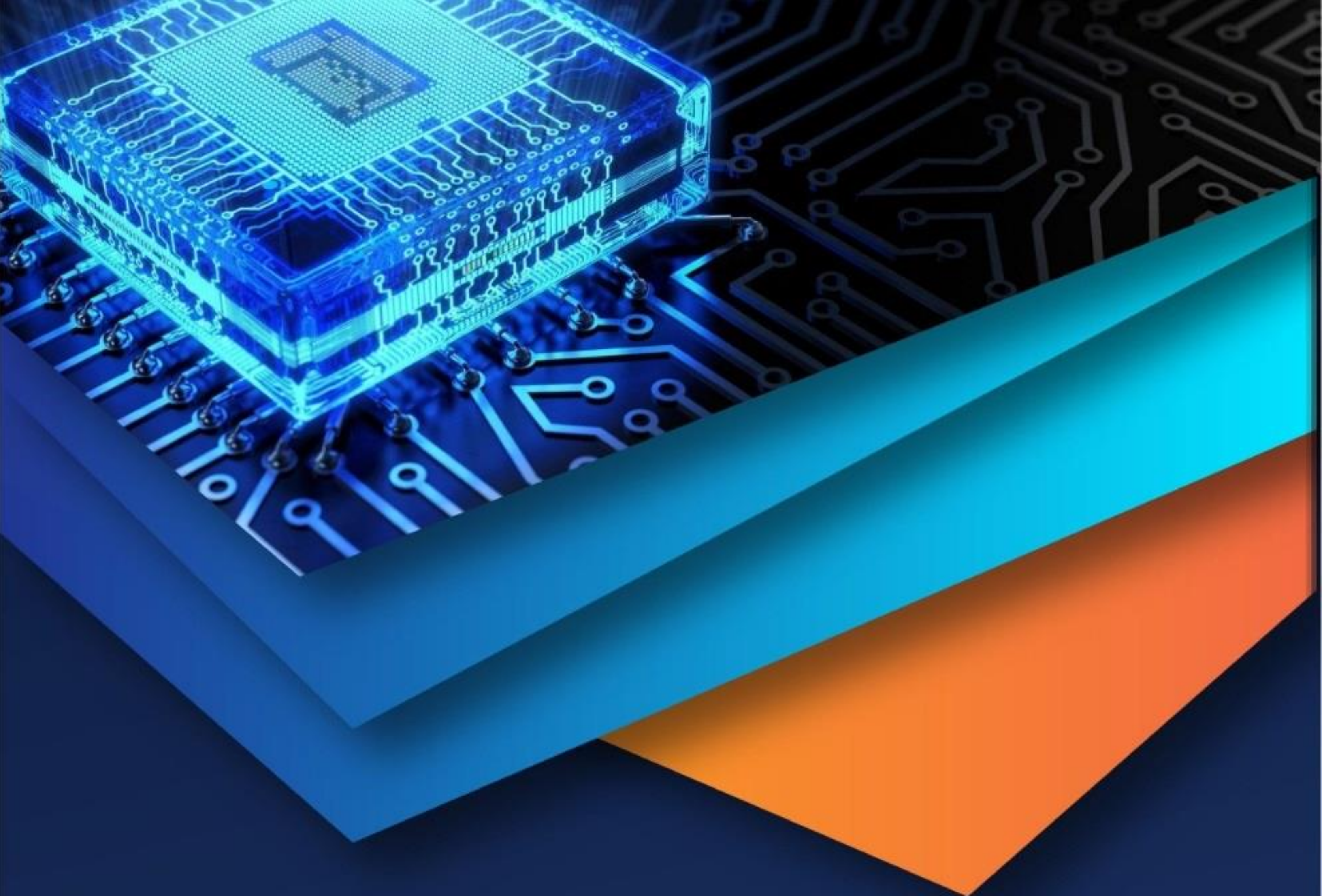

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