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DESIGN OF HYBRID VEHICLE

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ABSTRACT

There will soon be a day when all the oceans dry out of crude oil, and the atmosphere gets contaminated with harmful gases causing depletion in the ozone layer. That day is imminent. There has been a proliferate rise in population, demand in oil, oil price, and the ability to equalize the demand to supply stringently. The world is entirely dependent on fossil fuels, becoming an essential part of life. The environmental effects of combustion help us study and move into an alternative way of harnessing energy from renewable resources. This project discusses the diffusion of hybrid technologies in two-wheelers. A hybrid vehicle can reduce the consumption of fossil fuels and move into a less harmful way of powertrain efficiency. Usage of this technology in vehicles helps us achieve fuel economy, increased power, and pollution reduction. Once the production of IC engines is reduced, the production and demand for hybrid vehicles increases, allowing us to build a better world for maintaining sustainable development.

KEYWORDS: Pollution, Hybrid vehicle, Fossil fuel & Sustainable development

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Original Article

INTRODUCTION

In the present scenario, we see an excessive number of vehicles, and the ineffectiveness to manage the pollution increases. As the population increases, the utilization rate also increases day by day, which takes a toll on the environment.

A ubiquitous problem worldwide is the lack of effort taken to reduce the effects on the environment. A step forward would be the transition to hybrid electric vehicles. This project discusses a linear and gradual transformation from conventional vehicles to hybrid vehicles. However, it is not possible to stop an existing process and start a new leaf; a transition phase is required, and that is the role of a hybrid vehicle.

Conventional vehicles offer many advantages like long drive range, good performance, and easy refuelling. However, conventional vehicles have lethal disadvantages such as pollution and inefficiency in work conversion.

The hybrid engine in vehicles can reduce fossil fuel use, decrease pollution, and allow renewable energy sources for transportation. Optimistic solutions for the emission of carbon dioxide and increasing global warming rates are the hybridization of the vehicle; they use an internal combustion engine and can be fuelled like standard cars but have an electric motor, battery, and can be partially or wholly powered by electricity. Hybrid cars can be modified to obtain divergent objectives, such as improved fuel economy, an increase in power, or provide auxiliary power for electronic devices and power tools present in the vehicle. Many technologies like regenerative braking, electric motor drive, automatic start, or shutoff are used in hybrid vehicles to make them as reliable as conventional vehicles.

METHODS AND MATERIAL

Methodology

The schematic shown is the exact representation of the arrangement of the components used. The primary power source being the Li-ion battery pack delivers a peak voltage of 48v, and the structure of cells is made according to the restricted space available within the chassis. The battery is shaped, starting from the trunk going all the way down to the footrest.

A BLDC hub motor, which is mounted at the front hub, draws current from the battery pack through a non-fluctuating sine wave motor controller. A regenerative motor controller is connected in parallel with the motor to assist in charging during various riding modes.

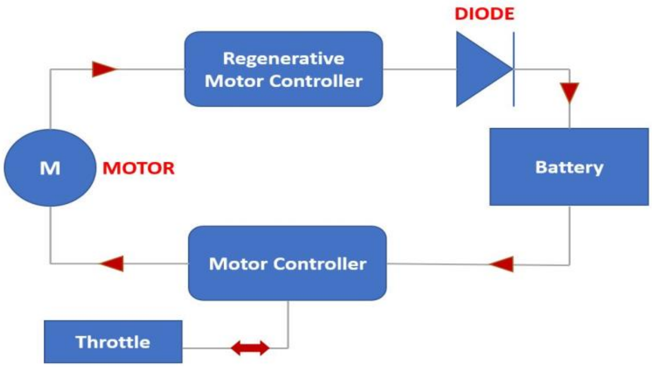

Figure 1: Working Block Diagram

A diode that can sustain high current is placed along the line of the regenerative motor controller's circuit. The diode placed in that position restricts the flow of current in one direction, therefore allowing charging. The charging modes are:

- IC engine drive

The vehicle is driven using the IC engine just like a standard conventional vehicle, and the motor thus acts as a generator. The regenerative motor controller is activated as the power is drawn into the battery.

- Down Hill

The roads that have a declining elevation will result in the vehicle's forward motion due to the stored gravitational potential energy and momentum. The resulting spin in the motor causes the charging of the battery.

- Charger

The conventional way of charging the battery is by using an adapter or drawing power from specific charging stations.

- Regenerative Braking

The process of getting the vehicle to a stop, brakes are applied at each of the wheels,and the braking power, which is the frictional force is acted on the wheel, releasing immense amounts of heat. This heat is just wasted. The regenerative braking solves this problem as the energy wasted in braking is converted into electrical energy, which can thus be stored in the battery. The motor gets coupled when brakes are applied and acts as a generator supplying power to the battery.

For example, if 1L of fuel was consumed to drive the vehicle up to a certain distance. The battery will provide the additional range that sums up the total distance and reduces the fuel consumed.

The electric powertrain is engaged, thus disengaging power from the engine and making the rear wheel a freewheel. The electric power from the battery is now used to drive the vehicle. The motor controller regulates the speed and current flow, and the diode prevents the current flow into the parallel regenerative circuit.

Once the battery's electric power is consumed, the motor drive is disengaged, and the engine drive is engaged. The engine now drives the vehicle. The motor's rotation is converted into electrical energy, which passes through the regenerative motor controller and recharges the battery.

COMPONENTS USED

- Lithium-ion battery pack
- Battery management system
- Motor controller
- Brushless DC hub motor
- Mechanical Throttle
- Electric Throttle
- Diode
- Regenerative Motor Controller

1. Lithium-Ion Battery

A lithium-ion battery is a rechargeable component where lithium ion’s movement occurs from a positive electrode to a negative electrode during charging and vice-versa while discharging. Lithium-ion batteries are standard rechargeable batteries for portable electronics, with a high energy density and low self-discharge.

The functional components of a li-ion battery are the positive electrode, negative electrode, and electrolyte. The negative electrode of a lithium-ion cell is conventionally made out of carbon. The positive electrode of a lithium-ion cell is made of metal oxide. The electrolyte used is lithium salt in an organic solvent. The electrodes reverse roles between cathode and anode, depending on the current flow direction through the cell.

The outer case is made of metal. The use of metal is essential here because the battery is pressurised. The metal case has a pressure-sensitive vent hole. This vent releases the extra pressure if the battery gets too hot. This metal case holds a spiral comprising a positive electrode, a negative electrode, and a separator. Inside the metal case, these layers are submerged in an organic solvent that acts as an electrolyte. The separator is a thin sheet of micro-perforated plastic which allows the ions to pass through. The movement of this li-ion happens at a slightly high voltage; hence each cell produces 3.7 volts.

2. Battery Management System

A battery management system is an electronic component that configuresa rechargeable battery. By monitoring its state, it protects the battery from working outside its safe operating space, and calculating the secondary data, reporting that data, controlling its environment, and balancing it is its primary function.It is used to monitor each cell's battery voltage, temperature, state of charge, health, power, safety and current. The battery management system also controls the recharging of the battery. The BMS computes and calculates the maximum charge current, maximum discharge current, delivered energy since the last charge cycle, total energy delivered, total operating time, and the total number of cycles. The BMS protects the battery from preventing it from over-current, over-voltage, under-voltage, over-temperature, under pressure, and ground faults.

3. Motor Controller

The motor controller is the most important component of the entire system. The power supplied is in the form of DC current. The DC current cannot be directly supplied to the motor as the motor is 3-phase. The controller takes in power from the battery, modifies it, and sends the output as a 3-phase current. A 32-bit microcontroller D79F9211 is used. It works at a frequency range from 70Mhz-100Mhz, and all the processing work that needs to be carried out is done in the factory while manufacturing. The main objective of the controller is to drive the MOSFETS and, in turn, drive the 3-phase motor. The MOSFETS are switches that can be controlled by the gates. The MOSFET drivers are arranged in an H-Bridge Circuit, and they control the gates of the 6 MOSFETS with precise timings.

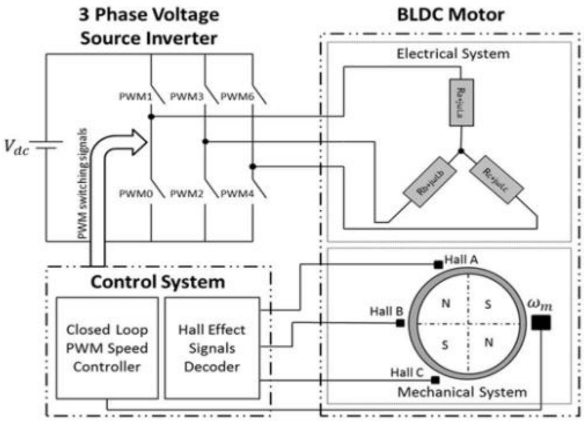

Figure 2a: Motor Controller

Here the PWM 1,2,3,4,5,6 are the MOSFET gates. The work of the controller is to produce the desired output when a DC input is given. The output is provided in the figure below.

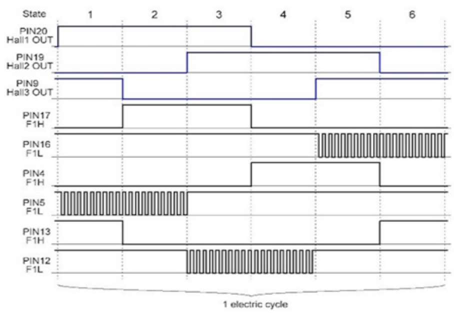

Figure 2b: Output Discrete Waveform

Infigure 2b, the pins from 12-17 are the gate controlling pins. 9, 19, 20 are hall feedback pins that give feedback. The hall pins tell the controller the exact position the stator of the motor is present. These waveforms are programmed using state machines that produce simple waveforms in a sequential way.

4. Brushless DC Hub Motor

Brushless DC motors are used to make the operation more reliable, efficient, and less noisy. They are comparatively lighter compared to brushed motors with the same power output.

The bushes in the DC motor wear out over time and may cause sparking; thus, the brush DC motor should never be used for operations that demand long life and reliability.

Working of brushless DC motor:

The rotor of the BLDC motor is a permanent magnet, and the stator has a coil arrangement, as shown in the figure. By applying DC power to the coils, the coils energize and become an electromagnet.

The operation of BLDC is based on simple force interaction between the electromagnet and permanent magnet. In this condition, when the coil is energized, the opposite poles of the rotor and stator are attracted. As the rotor approaches coil A, coil B is energized. As the rotor approaches coil B, coil C is energized. Following that, coil A is energized with the opposite polarity; this process is repeated.

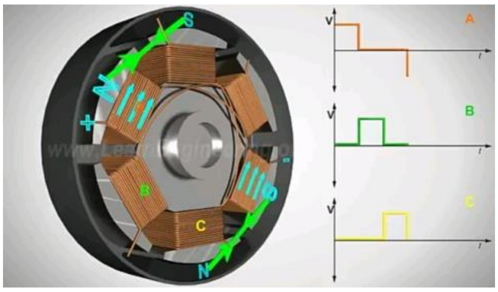

Figure 3: Brushless DC Motor

5. Mechanical Throttle

The throttle is used to increase, decrease, or vary the engine's power by regulating the inlet gases and airflow to the engine using a throttle cable.

6. Electric Throttle

The throttle consists of a hall effect sensor. Twisting the throttle varies the magnetic field's polarity and strength adjacent to the sensor, which in turn sends a voltage to the controller (usually between 0.8V to 4.5V); thus, controlling and regulating the speed of the vehicle.

Figure 4: Electrical Throttle

7. Diode

A diode has two terminals, one anode, and the other cathode. When forward biased, the anode voltage is higher than the cathode voltage. When the diode's voltage is more than the cut-in voltage, the diode conducts entirely. When reverse biased, there is a small reverse current known as leakage current. This leakage current increases when there is an increase in the magnitude of reverse voltage. It has a much higher maximum current rating when compared to a standard diode.

8. Regenerative Motor Controller

The traditional brushless DC motor has transitioned to the square wave control; this is simple to control and easy to realize. However, brushless DC motors have certain limitations like they cannot compete with conventional motors in the large or medium power range; this occurs due to the trapezoidal winding distribution. The appropriate solution would be using sine-wave control.

Sine wave control of brushless DC motors works on the basis where the motor winding generates the sine wave current by exerting a specific voltage to it; the motor torque is manipulated by fluctuating the amplitude and phase of the sine-wave current. The traditional trapezoidal wave control is comparatively different; here, the motor has a sine-wave current, which changes frequently and has no phase-change current mutation, which in turn reduces the operational noise and increases motor efficiency. There are two types of sine wave control: -

Simple Sine Wave Control

The motor winding is exerted with a specific voltage; this enables the motor's phase voltage to be a sine-wave. The phase current of the motor is a sine wave because the motor winding is an inductive load. The current phase and amplitude are controlled by manipulating the amplitude and the motor phase voltage.

Generally, the motor is exerted with a specific voltage to have sine phase voltage to the two ends of the winding. The common generation means include sine pulse-width modulator and space vector pulse-width modulator. Because the pulse wave modulator has a simple principle and easy realization, it is employed as the pulse-width modulator generation, which in turn leads to simple sine-wave control.

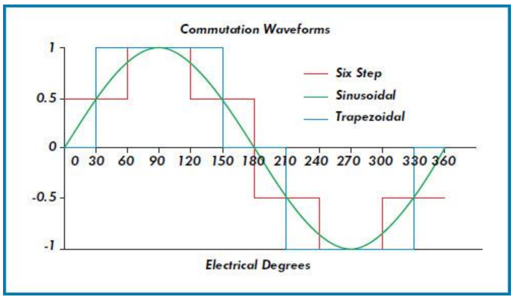

Figure 5: Sinusoidal Communication

WORKING

The front wheel is equipped with a BLDC hub motor, and the rear wheel is undisturbed. The power transmitted by the IC engine and the existing drive mechanism enables the front wheel to act as a generator. The hub motor is connected to the motor controller and a regenerative motor controller in parallel.

The usual way of starting the two-wheeler is carried out, and the driving remains the same. When the two-wheeler is on the run, the rear wheel drives the entire vehicle because the flywheel connects the engine to the rear wheel, the front wheel also rotates/moves. We use this principle to use the front wheel as an alternator, converting the wheel's rotational motion to electrical energy. The electrical components of the vehicle are all reversible processes. At one stage, the motor acts as a generator and, on the other stage, drives the vehicle.

The two-wheeler running on fuel drive helps the front wheel generate electricity and store this in the battery pack. Once the entire battery is charged or charged partially, we can disconnect the fuel source and disengage the engine drive making the rear wheel a freewheel. The front-wheel now drives the entire vehicle as the battery now supplies power to the motor through the motor controller. The vehicle now becomes a front-wheel drive. After complete utilization of power from the battery, we can switch to a state of charging by switching over to the engine drive mechanism. At this stage, the flow is reversed. The motor acting as an alternator is connected to the regenerative motor controller, which steps up the small voltages coming from the motor and converts the 3-phase into a terminal DC output, which will charge the battery. This successive process continues, and the consumption of fuel to travel distances is minimized. The usage of fuel, added with electricity, gives the vehicle an added advantage of covering large distances; this is how we quote: "No stationery charging units."

There need not be any charging stations nor any stationary charging unit to recharge the battery. Another approach would be charging using an AC power source from an adapter. Regenerative braking is self-present as the charging mechanism is continuous as and when the brakes are applied. A 1000w BLDC hub motor generates an output torque of about 40.6Nm when carrying a load of 180kgs, and the 48V 50Ah battery fulfills the requirement. The weight distribution of the Li-Ion battery pack is customized by repositioning the cells within. The air-cooled battery pack is placed with vents provided on the body of the vehicle for better air circulation, thus increasing the battery's life and maintaining safe operating temperatures.

The speed achieved by the motor is less compared to the IC engine. Comparing the two powertrains, the resultant will be that the distance achieved by burning 1L of fuel will increase the distance output by approximately three times. For example, if we can travel 40 km in 1L of fuel, we can cover three times more distance, which is approximately 120km by using the electric powertrain. Using 1L of fuel gives us 40km and switching to electrical power gives us around 80km. In reality, it looks like the vehicle's mileage graduates to a higher value along with less consumption of fuel and less harmful gas emissions.

The battery pack needs no charging; as a result, there is no extra cost added. The way the two-wheeler is ridden would remain the same with negligible changes seen from the outside. It behaves like a regular two-wheeler rather, producing more output for the same cost.Using eagle software, the circuit of the motor controller was designed.

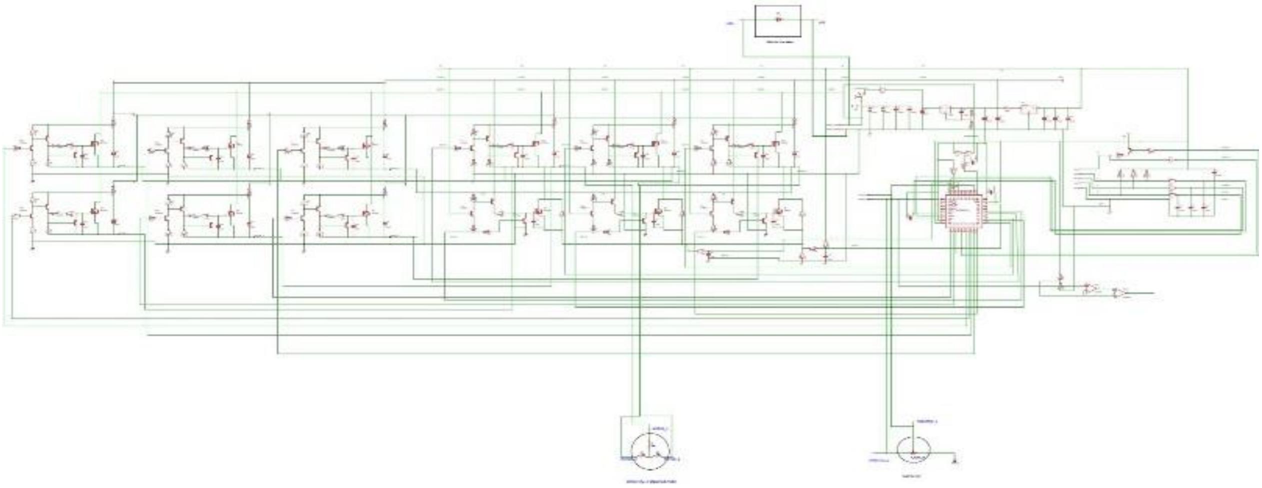

Figure 6: Internal Circuitry

GEOMETRICAL MODELLING

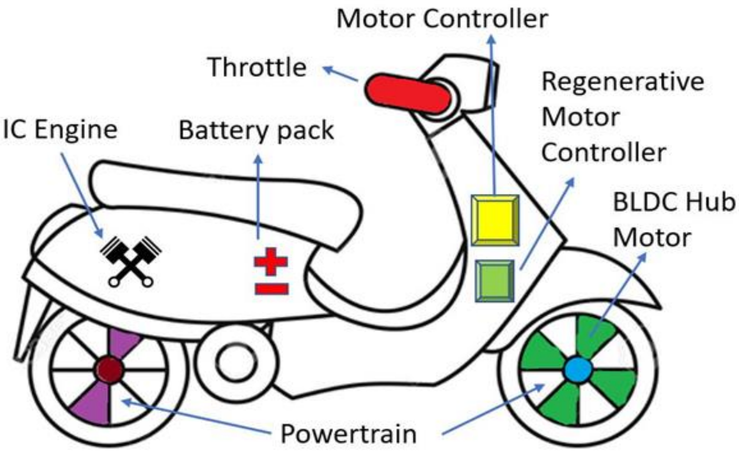

Figure 7: 2D Prototype Assembly

A prototype of the model was made with simple tools. The engine, flywheel, and the mechanical throttle are not disturbed. The battery is placed in the trunk and is extended to the footrest of the vehicle. An opening is made at the bottom of the boot's bottom surface, and the battery pack is held in place with clamps. The wiring is taken through the footrest to the front deck. The BLDC hub motor is attached to the front hub, and the wires are drawn up. The controllers are placed, and parallel wiring is established. The throttle wire is taken from the motor controller, and the electrical throttle is fixed next to the mechanical throttle without any significant alterations.

RESULTS

Vehicle weight = **180kg**

Gross weight(W)= 180x9.81= **1765.8N**

Weight on each drive wheel=1765.8/2= **882.9N**

Radius of wheel(R)= **0.3m**

Desired speed(V)=35km/hr= **9.722m/s~10m/s**

Acceleration time(T)= **40s**

Max road inclination(θ) = **2°**

Working surface = **Concrete**

Total Tractive Effort required (TTE)

TTE=RR+GR+FA

RR= Rolling resistance

GR= Grade friction

FA=Force required to accelerate to max velocity.

Rolling Resistance

RR= Wx ɰ(coefficient of friction of concrete)

RR=1765.8x0.01 = **17.658N**

Grade Resistance

GR= Wx Sin(θ)

GR= 1765.8xSin(**2°**)= **61.625N**

Acceleration Force

FA=(WxV)/(9.81xT)

FA=(1765.8x9.722)/(9.81x40)= **43.749N**

TTE=RR+FA+GR

TTE=17.658+61.625+43.749= **123.032N**

Torque at Wheel

T=TTExRxResistance factor(10%-15%)

T=123.032x0.3x1.1= **40.6Nm**

Electric Power

P=2πNT/60

P=Motor Power

N=Speed of motor

T=Torque

T=(1000x60)/(2πx310)= **30.8Nm(No load)**

Circumference of wheel**=** 2πR= **1.88m**

Speed= **5.166rps** = **9.712m/s**

In 1 second, the wheel covers.

Distance= 5.166x1.88 = **9.712m**

Speed= 9.712m/s ≈ 35km/hr

Battery Calculation

Capacity= 50Ah

The Ccrrent required by the motor.

I=P/V = 1000/48 = **20.83A**

Time taken to discharge the battery

T=50/20.83 = **2.4hrs**

Range calculation

Distance = Speed x Time

D= 35 x 2.4 = **84km**

Therefore, the estimated range is approximately 84km of electric motor and assumed 1L mileage to be 40km gives a range of about 120km.

CONCLUSIONS

A step forward would be the transition to hybrid electric vehicles.

The vital advantage of an electric-hybrid motor includes the reduced consumption of fuel, which in turn reduces pollution, causing less harm to the society and atmosphere. The resupply of fuel is drastically reduced, improving sustainable development.

Improving sustainable development will augment the potential of future generations.

Further travel is possible when the use of electric-hybrid motors is implemented. The principle of regenerative braking helps transform kinetic energy into electrical energy; this energy is stored back in the battery; this allows the vehicle to be economical and efficient.

In case of the engine failure, the electric motor will take over to prevent being stranded.

Switching over to Hybrid vehicles is a great deed and will be beneficial in the long run.

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