DESIGN OF A HYBRID ELECTRIC VEHICLE

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DESIGN OF A HYBRID ELECTRIC VEHICLE

A Thesis submitted in partial fulfillment of the requirements for the degree of

Bachelor of Technology in "Electrical Engineering"

By

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CERTIFICATE

This is to certify that the thesis entitled "**Design of a Hybrid Electric Vehicle**", submitted by **Toshali Mohanty (Roll. No. 109EE0286)** in partial fulfilment of the requirements for the award of **Bachelor of Technology** in **Electrical Engineering** during session 2012-2013 at National Institute of Technology, Rourkela. A bonafide record of research work carried out by them under my supervision and guidance.

The candidates have fulfilled all the prescribed requirements.

The Thesis which is based on candidates' own work, have not submitted elsewhere for a degree/diploma.

In my opinion, the thesis is of standard required for the award of a bachelor of technology degree in Electrical Engineering.

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Dedicated to

My parents

ABSTRACT

A **'gasoline-electric hybrid car'** or **'hybrid electric vehicle'** is a vehicle which relies not only on batteries but also on an internal combustion engine which drives a generator to provide the electricity and may also drive a wheel. It has great advantages over the previously used gasoline engine that drives the power from gasoline only. It also is a major source of air pollution. The objective is to design and fabricate a two wheeler hybrid electric vehicle powered by both battery and gasoline. The combination of both the power makes the vehicle dynamic in nature. It provides its owner with advantages in fuel economy and environmental impact over conventional automobiles. Hybrid electric vehicles combine an electric motor, battery and power system with an internal combustion engine to achieve better fuel economy and reduce toxic emissions. In HEV, the battery alone provides power for low-speed driving conditions where internal combustion engines are least efficient. In accelerating, long highways, or hill climbing the electric motor provides additional power to assist the engine. This allows a smaller, more efficient engine to be used. Besides it also utilizes the concept of regenerative braking for optimized utilization of energy. Energy dissipated during braking in HEV is used in charging battery. Thus the vehicle is best suited for the growing urban areas with high traffic.

Initially the designing of the vehicle in CAD, simulations of inverter and other models are done. Equipment and their cost analysis are done. It deals with the fabrication of the vehicle. This includes assembly of IC Engine and its components. The next phase consists of implementing the electric power drive and designing the controllers. The final stage would consist of increasing the efficiency of the vehicle in economic ways.

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ABBREVIATIONS AND ACRONYMS

HEV	-	Hybrid Electric Vehicle
AC	-	Alternating Current
DC	-	Direct Current
BLDC	-	Brushless DC
IC	-	Internal Combustion
CVT	-	Continuously Variable Transmission
CAD	-	Computer-aided Design
PWM	-	Pulse Width Modulation
VSI	-	Voltage Source Inverter
MATLAB	-	Matrix Laboratory

CHAPTER 1

Introduction

1.1 MOTIVATION:

Around 93% of today's automobiles run on petroleum based product, which are estimated to be depleted by 2050 [1]. Moreover, current automobiles utilize only 25% of the energy released from petroleum and rest is wasted into the atmosphere [2]. Despite recent efforts to improve fuel efficiency and reduce toxic emissions in cars, emissions have continued to increase steadily in the past two decades.

For preservation of gasoline for future and increasing the efficiency of vehicle an electric vehicle can be a major breakthrough. An electric vehicle is pollution free and is efficient at low speed conditions mainly in high traffic areas. But battery charging is time consuming. Moreover, it cannot provide high power required by drives during high speed conditions or in slopes of hilly areas. Gasoline engine proves its efficiency at higher speeds in high ways and waste a lot of energy in urban areas. A hybrid vehicle solves these problems by combining the advantages of both the systems and uses both the power sources at their efficient conditions. The objective of this project aims at better utilization of fuel energy and reduces dependence on non-renewable resources using latest technology. The implementation involves development of HEV that uses battery as well as gasoline power for propulsion of vehicle.

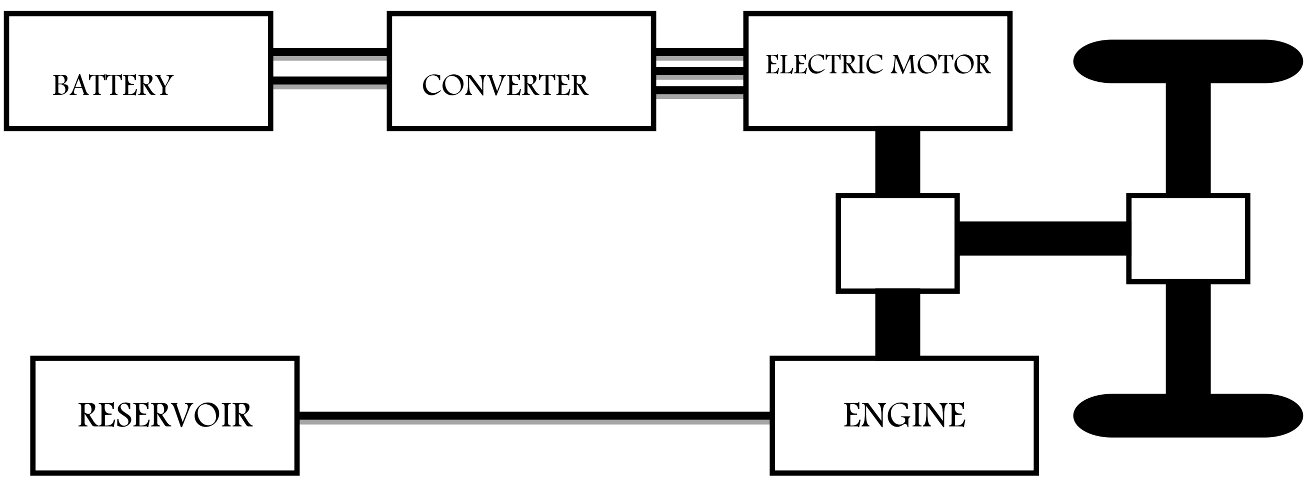
1.2 CONCEPT OF HEV:

A **'gasoline-electric hybrid vehicle'** is an automobile which relies not only on gasoline but also on electric power source. In HEV, the battery alone provides power for low-speed driving conditions. During long highways or hill climbing, the gasoline engine drives the vehicle solely. Hybrid electric vehicles comprise of an electric motor, inverter, battery as electric drive and an internal combustion engine with transmission connected as gasoline based drive. It is to achieve better fuel economy and reduce toxic emissions.

It has great advantages over the previously used gasoline engine that is driven solely from gasoline. This hybrid combination makes the vehicle dynamic in nature and provides its owner a better fuel economy and lesser environmental impact over conventional automobiles.

1.3 BASIC DESIGN OF HEV:

The basic design consists of a dc power source battery. The battery is connected to inverter that is fed to a BLDC motor that works on AC. The motor is attached to the front wheel of the two wheeler vehicle. As the motor rotates the attached wheel rotates too, thus, leading to vehicle motion. At low speeds this mode of propulsion is used. The next phase consists of an IC engine that moves the piston continuously. This is connected to the transmission and thus, the vehicle moves.



1.1 Schematics of HEV

1.4 ADVANTAGES OF HEV:

HEVs have been vehicles of numerous advantages. Hybrids do indeed get superior gas mileage. They use less gasoline, and therefore emit less greenhouse gas. Thus the problem of environmental pollution can be avoided to certain extent. Apart from that they use less gasoline

in comparison to the other vehicles of same power that run only on gasoline. Thus this reduces the extreme dependence on gasoline which is a non-renewable source of energy. This encourages the method of sustainable development that has been the topic of concern in the modern society. Moreover, HEVs mode of operation are maximum efficient to the conditions, i.e, at low speed and high traffic areas where gasoline engine is least efficient with a lot of energy wasted, HEV moves with power from battery. At up slopes where high power is required and battery is inefficient, gasoline power is used for vehicle motion.
Thus the advantages of HEV make it superior than any other vehicle of today.

1.5 OVERVIEW OF PROPOSED WORK DONE

Many a literature are used to carry out the project which includes notes on HEVs, electric drives, energy management, batteries, internal combustion engine, etc. Reference [1]-[2] gives us the data of the global scenario regarding the vehicle dependence on non-renewable resource gasoline and the expected year of depletion of the product. It gave a detailed discussion on importance of development of other types of vehicles such that too much dependence on gasoline based can be reduced. Reference [3]-[4] gives an overview about the electric drive technology. Reference [5] describes about battery technology available in the market. Reference [5] tells about the various batteries and their advantages. Reference [6] gives theories about motors, their efficiency as per the application and about the controller. References [7]-[8] describe the internal combustion engine, ways to increase their efficiency etc. Reference [9]-[11] gives an overview of HEV and its associated advantages.

1.6 THESIS OBJECTIVES:

The following objectives are to be achieved at the end of the project.

a) Design and virtual analysis of the vehicle.

b) Designing & Assembling of IC Engine.

c) Designing & Assembling of the Electric Power Drive.

d) Designing a two wheeler vehicle with front wheel powered by electric motor and rear wheel drive powered by an Internal Combustion Engine.
e) A switching circuit used to switch from IC Engine to the electric power and vice versa.
f) Implementation of control algorithm by microcontroller
g) Efficiency calculation of vehicle.

1.7 ORGANISATION OF THESIS:

The thesis is organised into seven chapters including the chapter of introduction. Each chapter is different from the other and is described along with the necessary theory required to comprehend it.

Chapter2 focuses on describing the basic concept of Hybrid Electric Vehicle. The basic schematic of Hybrid Electric Vehicle is shown in the section. Through an advanced CAD Model of two-wheeler proposed Hybrid Electric Vehicle the exact design model of the vehicle is illustrated. The advantages of HEV is described and analysed. The next section of the chapter explains the working of HEV through a neat block diagram.

Chapter3 describes electric drive and its components. In the initial section of the chapter an introduction to electric vehicle is described. Next the MATLAB Simulink model is shown with proper demonstration to the circuit. The next section gives overview of various components of electric drive. The battery and its various types are described. With a proper comparison between the types and associated discussions the best suited battery for HEV application is chosen. Then PWM inverter used in the vehicle is described and analysed. The last section of the chapter contains the discussions on the BLDC motor used and its advantages.

Chapter4 describes the gasoline based engine. In the section the theories related to gasoline engine, carburetion etc. are discussed. The CAD model of IC engine is illustrated.

Chapter5 describes methods for efficiency calculation of vehicle. Various efficiencies are judged and calculated for proper modelling of a vehicle. The efficiencies include indicated

Thermal Efficiency, brake thermal efficiency, mechanical efficiency, specific fuel consumption, electric drive efficiency etc.

Chapter6 presents the analysis of various components of the vehicle. The analysis includes the thermal analysis of the engine. It is done to avoid damages to the engine. The analysis plot shows the portions of engine prone to high, medium or low temperature. According to the analysis the designing of the engine is done. The next discussion is on the stress analysis of the chassis. Through the analysis the chassis designing can be done with proper stress distribution. The next section contains the MATLAB simulation of the three phase PWM VSI. It also includes the simulation of electric drive with plot between torque-time, armature current-time, voltage-time and speed-time.

Chapter7 concludes the work performed so far. The possible limitations in proceeding research towards this work are discussed. The future work that can be done in improving the current scenario is mentioned. The future potential along the lines of this work is also discussed.

CHAPTER **2**

Hybrid Electric Vehicle

2.1 INTRODUCTION

The project discloses a hybrid system consisting of an Electric and Internal Combustion(IC) based power drives. The front wheel is being propelled by battery and the rear wheel is powered by gasoline, i.e, it includes a single cylinder, air cooled internal combustion engine and a BLDC motor based electric power drive used for hybrid powering of the vehicle. The controller is designed to implement the switching between IC Engine and Electric motor depending on the power requirement and load conditions.

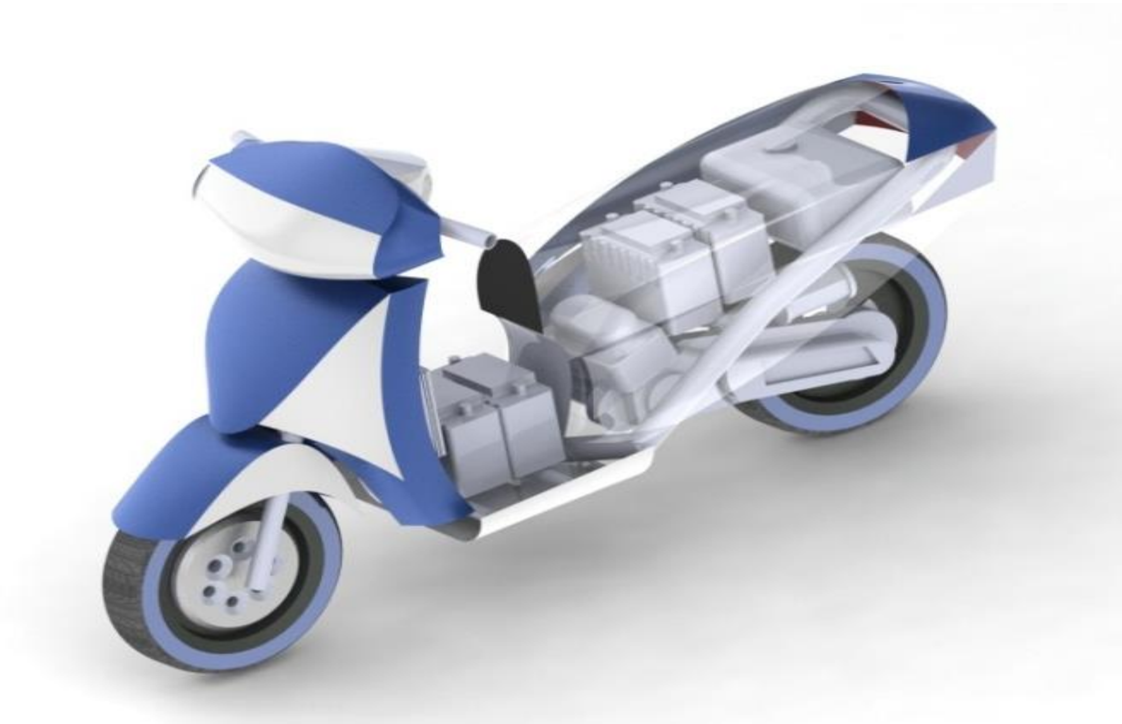
2.2 CAD MODEL OF HEV

2.1 Rendered View


2.2 Rear Rendered View

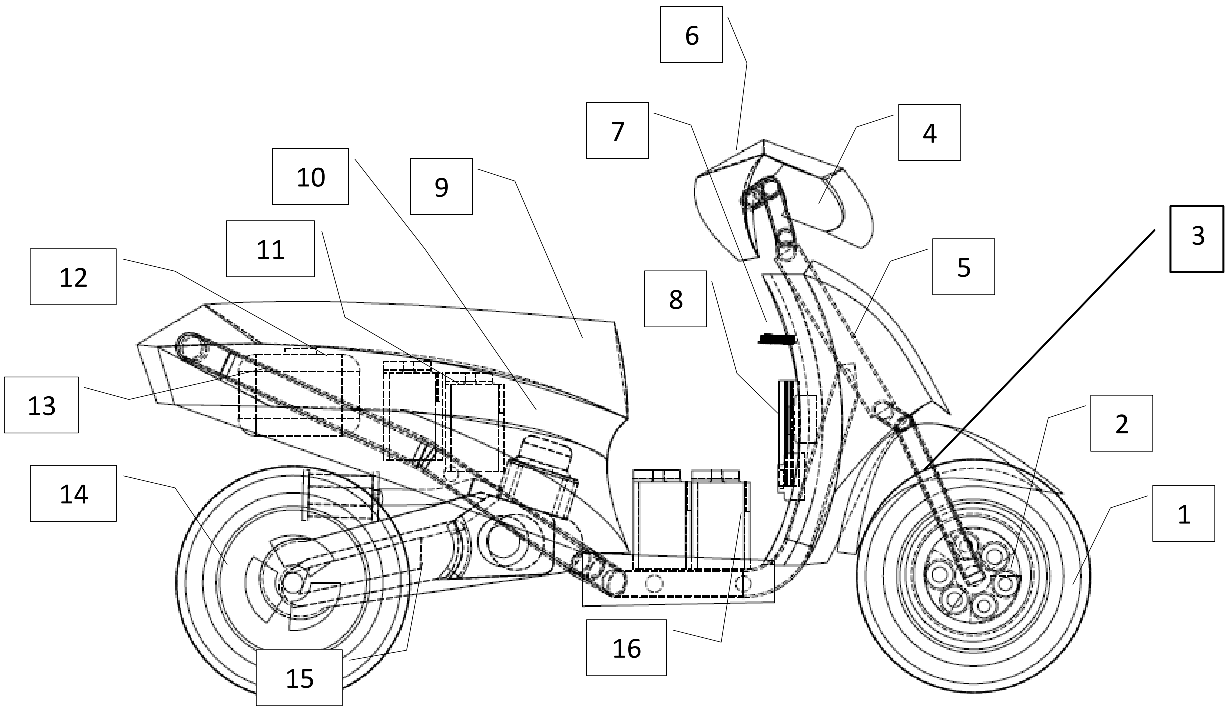

2.3 Side Rendered View

2.4 Front Rendered View



2.5 Transparent Body Frame Isometric view

2.6 Transparent Body Frame Isometric view



2.7 Wire Frame Model Side View

2.2.1 Components:

1) Tyre 2) Hub Motor 3) Suspension 4) Headlamp 5) Body Cover 6) Display

7) Microcontroller 8) Hub Motor Controller 9) Seat 10) Engine 11) Front Battery

12) Fuel Tank 13) Chassis 14) Rear Tyre 15) Transmission 16) Rear Battery

2.2.2 Description of the diagrams:

Fig. 1 is the rendered design of the hybrid vehicle modelled in CAD software.

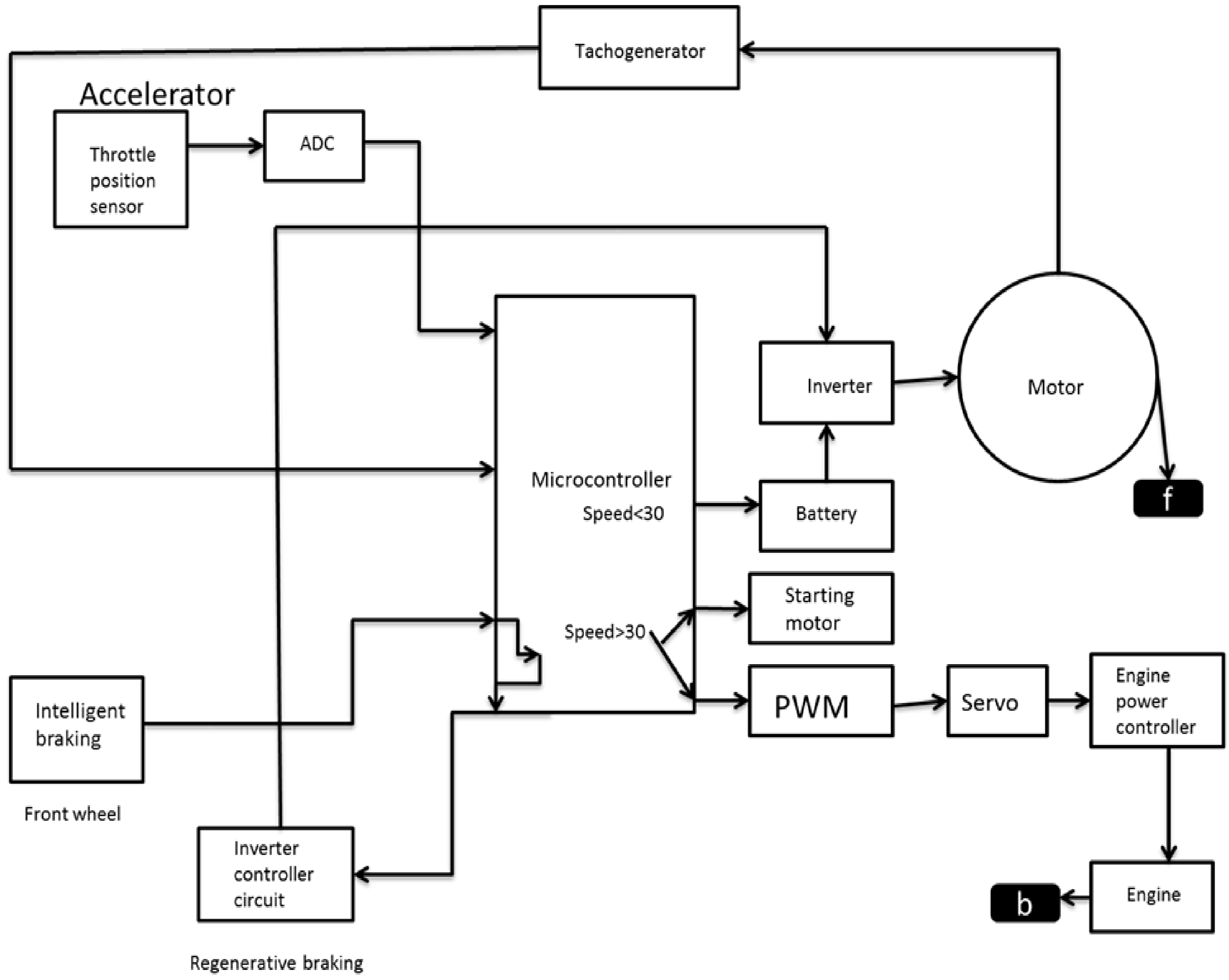
Fig 2, fig 3, fig 4 are rear, side and front view of the vehicle respectively.

Fig 5, figs 6 consist of transparent body frames to show the interior components of the design.

Fig 7, fig 8, fig 9 are the drafted view of side, top and isometric views of the vehicle respectively.

The vehicle at lower speed act as front wheel drive and at high speed gets switched to rear wheel drive automatically. Component 1 in Fig 7 shows the attachment of tyre with the hub motor (2 of Fig 8). There is no need for any gear reduction since the torque produced is sufficient enough to drive the vehicle. The axel of the motor is connected to the suspension (3 of Fig 8). Suspension is connected to the handle which is connected to the main chassis. Accessories such as headlamp (4 of Fig 8), display (6 of Fig 8) are included as user aid. A microcontroller (7 of Fig 8) powered up from battery, performs the switching from electric to internal combustion or vice versa as per the requirement. It senses throttle position and controls the hub motor speed via controller circuit and the IC Engine via servo motor to control speed of rear wheel. Due to space constraints, two batteries (16 of Fig 8) are placed in front and two are placed near the fuel tank. Engine (10 of Fig 8) is connected to the main chassis and seat (9 of Fig 8) is situated above the engine. CVT is connected to the crank shaft of the engine to avoid any shocks while switching and it makes the controlling simpler and easier.

2.3 BLOCK DIAGRAM OF HEV

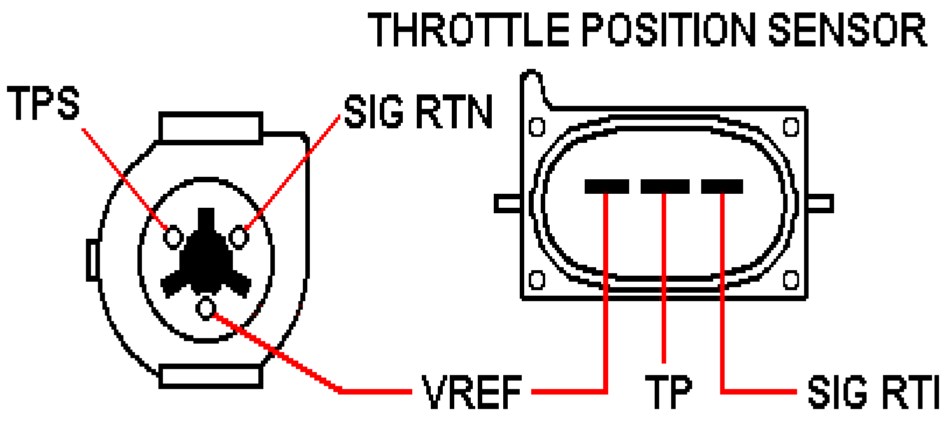


2.8 Block diagram of HEV

2.4 WORKING OF HEV

In HEV, the battery alone provides power for low-speed driving conditions where internal combustion engines are least efficient. In accelerating, passing, or hill climbing where high power is required battery provides power to electric motor as an additional power to assist the engine. This allows a smaller, more efficient engine to be used.

A **throttle position sensor** (TPS) is a sensor used to monitor the position of the throttle in an internal combustion engine. It consists of a hall sensor. When the accelerator throttle angle changes magnetic field is created and it creates voltage across position sensor terminal. Thus for various angles, various voltages are obtained.



2.9 Throttle position sensor

TABLE 2.1: Throttle position sensor

Throttle Position Sensor		
Rotational Angle		**Signal Voltage**
0	Under Travel	0.000
10		0.450
13	Closed Throttle	0.901
20	-	1.440
30		1.900
40		2.370
50		2.840
60		3.310
70		3.780
80		4.240

84	Full Throttle	4.538
90	Over Travel	4.538
100		5.00
were calculated for VREF = 5.0 volts.		

HEV consists of a throttle position sensor, i.e, hall sensor. It gives voltage as output with respect to the angle displacement in the accelerator. The analog voltage generated is converted to digital through ADC and is given to microcontroller. If the speed corresponding to the angle deviation in accelerator is less than 30km/hr then the relay is switched on. The relay switching completes the circuit of the battery, inverter and hub motor; and vehicle is motioned by electric power. If the speed directed by accelerator is greater than 30km/hr, then the engine is started by closing the circuit of starting motor through a relay. The starting motor circuit is activated for five hundred milliseconds such that the vehicle is started. Once the vehicle starts the valve of engine for gasoline intake opens by servo motor. The amount of opening is controlled by the PWM generated by the microcontroller as directed by the accelerator.

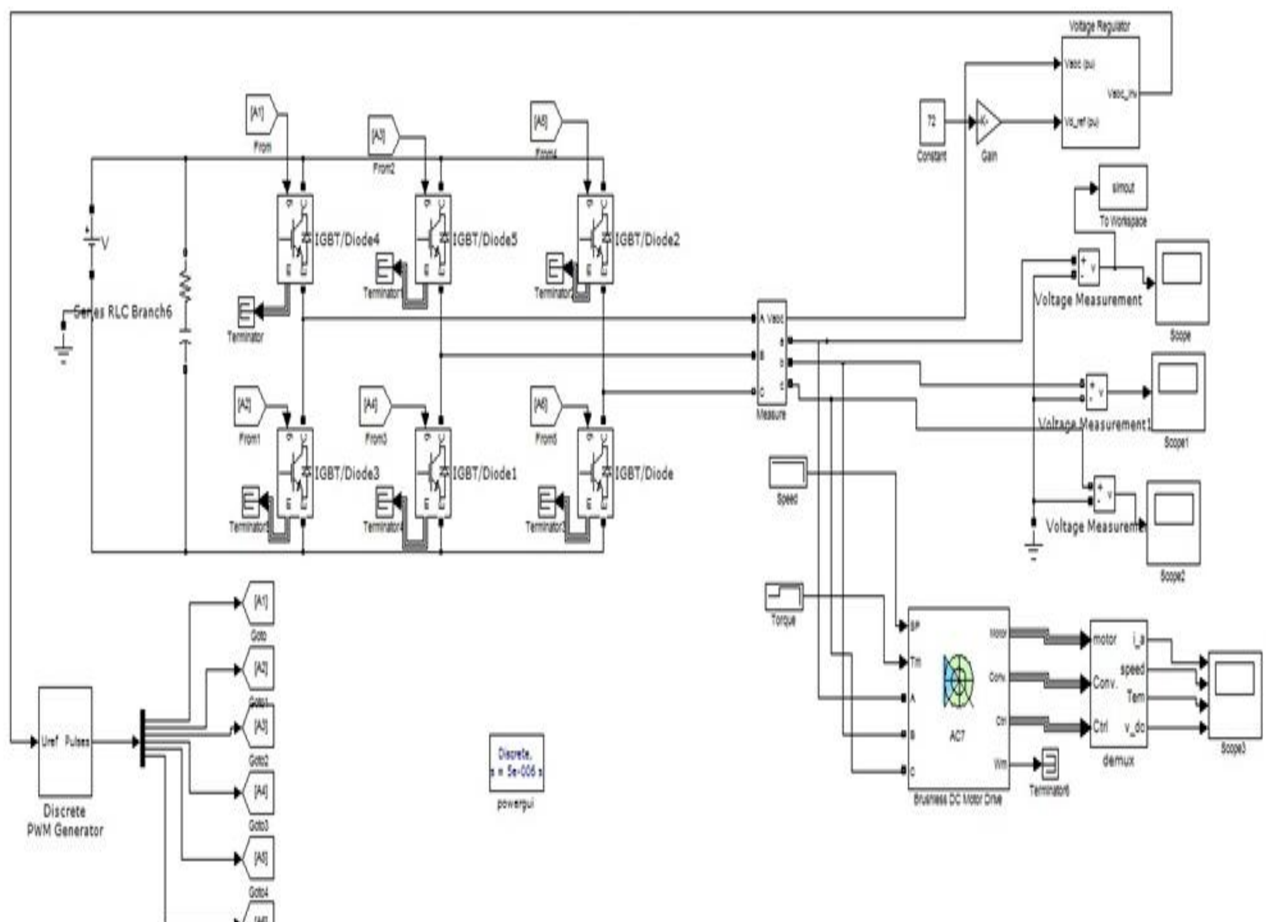
CHAPTER **3**

Electric Based Front Wheel Drive and Its Components

3.1 INTRODUCTION

Electric Vehicle consists of battery, inverter and BLDC motor. It is a part of hybrid electric vehicle that is propelled during low speed condition. It is pollution free as there is no combustion of fuel involved. It is a soundless vehicle. It is a very efficient vehicle as there is no loss of energy involved.

3.2 MATLAB CIRCUIT DIAGRAM



3.1 MATLAB Circuit diagram of electric vehicle

The electric vehicle circuit consists of a battery. The battery is connected to a PWM VSI to convert DC voltage to AC. This AC is fed to the BLDC motor. BLDC motor has several advantages in comparison to other motors. It has wide speed variations as DC motor but do not have the drooping characteristics as is there in DC motor. The output is continuously sensed by voltage sensor. It is given to the voltage regulator. The function of voltage regulator is to convert three phase RYB voltage to dq axis. It is then compared and the error is fed to PID controller. Thus the required voltage is obtained and is fed to PWM generator as reference. PWM generator generates pulses to be fed to the IGBT/Diode switches. Thus a regulated output voltage is obtained from the closed loop VSI and is given to BLDC motor for best output.

3.3 COMPONENTS OF ELECTRIC DRIVE

3.3.1 BATTERY

Hybrid Electric Vehicle uses battery as one of its power source for vehicle motion during at low power conditions. Batteries are devices that consist of electrochemical cells and provide electrical energy converted from stored chemical energy [5]. Generally batteries are of two types: primary batteries that are disposable and secondary batteries that are rechargeable. Secondary batteries are preferred for vehicles as they can be rechargeable.

There are six major rechargeable batteries available today. They are as follows: lead-acid (Pb-acid), nickel-cadmium (NiCd), nickel-metal hydride (NiMH), lithium-ion (Li-ion), lithium-polymer (Li-poly), zinc-air [5]. The basic performance characteristics of the battery which influence the design are as follows:

- **Charge/discharge ratio (c/d ratio):**
  The charge/discharge ratio is defined as the Ah input over the Ah output with no net change in the state of charge. Less the c/d ratio better is the battery.
- **Round trip energy efficiency:**
  The energy efficiency over a round trip of full charge and discharge cycle is defined as the ratio of the energy output over the energy input at the electrical terminals of the battery. More the round trip energy efficiency better is the battery.
- **Charge efficiency:**
  The charge efficiency is defined as the ratio of the Ah being deposited internally between the plates over that delivered to the external terminals during the charging process. More the charge efficiency better is the battery.

- **Internal impedance:**

  Batteries have internal resistances. For the internal resistances present, the battery cannot operate in the full efficient condition. The power delivered at load decreases and hence less is the internal resistance of battery better is its performance.

- **Temperature rise:**

  Temperature rise is an important factor for batteries as beyond a certain temperature value the battery may lose its charge capacity. Thus, more the temperature sustaining value of the battery better is its efficiency and lifetime.

- **Life in number of c/d cycles:**

  Batteries have a particular life in number of c/d cycles. More the value better is the battery.

TABLE 3.1: Average Cell Voltage during Discharge in Various Rechargeable Batteries

Electrochemistry Cell	**Voltage**
Lead-acid	2.0
Nickel-cadmium	1.2
Nickel-metal hydride	1.2
Lithium-ion	3.4
Lithium-polymer	3.0
Zinc-air	1.2

TABLE 3.2: Battery Characteristics Affecting Thermal Design

Battery	**Operating temperature range °C**	**Overcharge Tolerance**	**Heat capacity Wh/kg-K**	**Mass density kg/liter**	**Entropic heating on discharge W/A-cell**
Lead-acid (Pb-acid)	–10 to 50	High	0.35	2.1	–0.06
Nickel-cadmium (NiCd)	–20 to 50	Medium	0.35	1.7	0.12
Nickel-metal hydride	–10 to 50	Low	0.35	2.3	0.07
Lithium-ion	10 to 45	Very Low	0.38	1.35	0
Lithium-polymer	50 to 70	Very low	0.40	1.3	0

TABLE 3.3: Specific Energy and Energy Density of Various Batteries

Battery	Specific Energy Wh/kg	Energy Density Wh/liter	Specific Power W/kg	Power Density W/liter
Lead-acid (Pb-acid)	30–40	70–75	~200	~400
Nickel-cadmium (NiCd)	40–60	70–100	150–200	220–350
Nickel-metal hydride	50–65	140–200	~150	450–500
Lithium-ion	90–120	200–250	200–220	400–500
Lithium-polymer	100–200	150–300	>200	>350
Zinc-air	140–180	200–220	~150	~200

TABLE 3.4: Life and Cost Comparison of Various Batteries

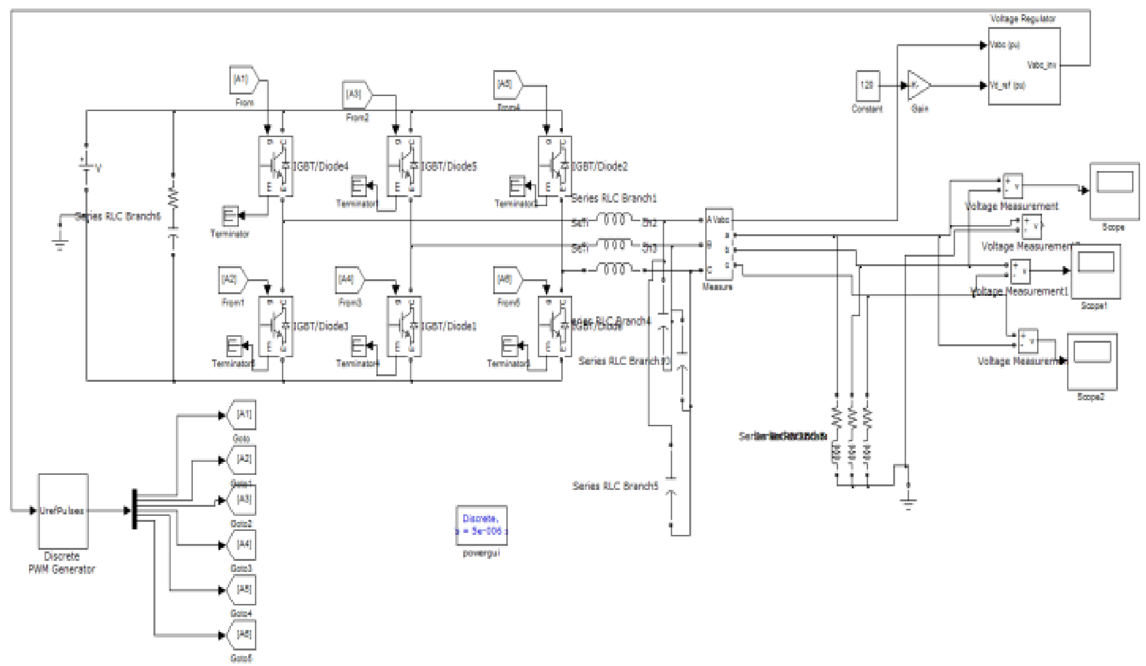
Battery	Cycle life in full discharge cycles	Calendar life in years	Self discharge rate %/month at 25 °C	Relative cost $/kWh
Lead-acid (Pb-acid)	500-1000	5-8	3-5	200-500
Nickel-cadmium (NiCd)	1000-2000	10-15	20-30	1500
Nickel-metal hydride	1000-2000	8-10	20-30	2500
Lithium-ion	500-1000	-----	5-10	3000
Lithium-polymer	500-1000	-----	1-2	>3000
Zinc-air	200-300	-----	4-6	------

The performance characteristics and properties of various electrochemistries presented in the preceding sections are summarized and compared . It is noted that despite of little advantages in all the factors, the overall cost of the lead-acid battery is low compared to NiCd, NiMH and Li-ion batteries. Because of its least cost per Wh delivered over the life, the lead-acid battery is best suited for vehicle application where low cost for customers are necessary.

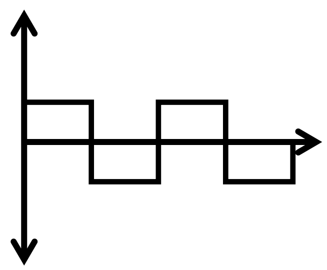
3.3.2 THREE PHASE INVERTER

In a three phase voltage source inverter bridge, controlled switching with the help of IGBT is used to control voltage in normal operation, and a parallel diode is connected to make the inverter bidirectional in nature. AC voltage is obtained by switching the IGBT switches in a specific pattern to obtain bipolar square two level waveform.

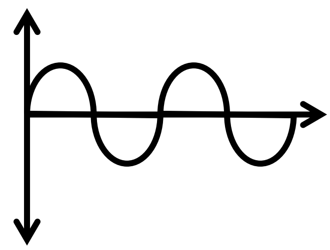
The bipolar square wave results in high harmonic content in the output. Use of filter makes the model costly and prohibits it from becoming bidirectional as concluded from simulation outputs.



3.2 Closed loop PWM VSI model



3.3 Output of PWM VSI without filter



3.4 Output of PWM VSI with filter

In the three phase PWM VSI, high dv/dt switching leads to introduction in harmonics to the circuit. But its low cost and small size makes it suitable to be used for two-wheeler hybrid electric vehicle.

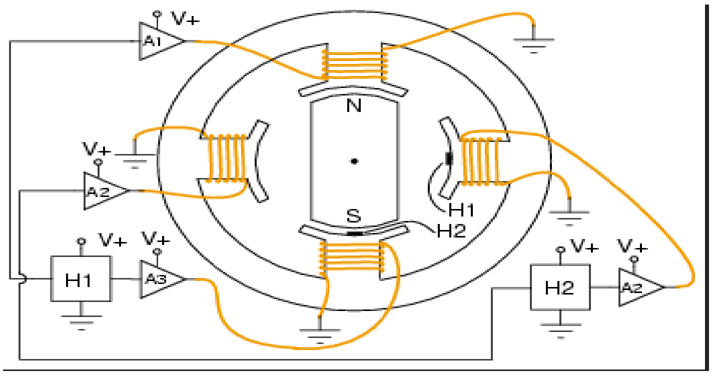
3.3.2.1 ADVANTAGES OF PWM VSI

- It gives constant voltage ouput.
- It gives square wave output which almost resembles trapezoidal wave required by BLDC motor.
- Smaller in size
- Less cost

3.3.3 BLDC MOTOR

BLDC motor is a closed loop synchronous motor. It has all the characteristics of DC Motor with some added features. It advantages are as follows:

- It is cheap.
- It can save 30% to 50% of power consumed by a normal motor and has high efficiency of 80% to 90%.
- It is small in size. It can have high torque at low speed.
- Speed range can be customized
- Replace the AC + frequency equipment minimizing harmonics introduction to the circuit.



3.5 Diagram of BLDC Motor

CHAPTER **4**

Gasoline Based Rear Wheel Drive and Its Components

4.1 GASOLINE ENGINE

An engine is a device that transforms one form of energy to another and if an engine converts thermal energy to mechanical works, it is called as heat engines. A heat engine converts the stored chemical energy of the fuels to thermal energy and finally this thermal energy is converted to mechanical work. Different types of engines are available such as: Internal Combustion, External Combustion, Reciprocating, Rotary etc. [7]. Internal Combustion engine delivers higher thermal efficiency and moreover weight of these engines is quiet low as compared to the powered delivered by them. There are some disadvantages as well, such as the vibration generated and the limitation of fuel variety to be used. Considering all the factors, reciprocating internal combustions are the most suitable in two wheelers.

Four stroke engines provide greater efficiency that two stroke engines and the emissions released into the atmosphere are less. Since the compression ratio is lower for smaller engines, spark based ignition system is preferred and gasoline is used as fuel.

A 100 cc, four stroke, single cylinder, air cooled petrol engine has been used which has carburetted type fuel supply system and magneto based spark ignition system.

4.2 CARBURETION

Spark based ignition engines use volatile liquids as fuels, thus the preparation of fuel air mixture is done outside the engine cylinder. The purpose of carburetion is to provide a combustible mixture of fuel and air in the required quantity and quality for efficient operation of engine under all conditions [8].Under normal conditions it is desirable to run the engine on the maximum economy mixture, and for quick acceleration rich mixture is used. Due to the downward movement of the piston, air is sucked into the cylinder, creating a lower pressure in the gas chamber. In carburetor, air passing through a tube which contains fine orifice are exposed to the atmosphere. The rate of fuel delivered depends on the pressure difference. A throttle valve controls the volume of the air that needs to be drawn.

Air cooled system: In this, a current of air is made to flow past the outside of the cylinder barrel, outside surface area of which has been considerably increased by providing cooling fins. The heat transfer rate is quiet low between metal and air, thus suitable for light weight engines. Cooling fins are cast integral with the cylinder and cylinder head to obtain maximum heat transfer. The heat dissipating capacity depends on both cross-section and length.

Magneto based ignition system: Magneto is a special type of ignition system with its own electric generator to provide the necessary energy for the system. A magneto when rotated by the engine is capable of producing a very high voltage and does not need a battery as a power source. Maintenance problems are less in magneto based system as there is no battery.

4.3 CAD MODEL OF IC ENGINE

4.1 CAD Model of IC engine

A single cylinder, gasoline based air cooled engine is designed in computer aided software, comprising of part modelling with part assembly. An engine consist of various parts such as piston, cylinder head, cam shaft, chains, timing controlling, fuel supply system, spark ignition system.

CHAPTER **5**

Efficiency of Power Drive

5.1 INTRODUCTION

Efficiency is indicated as the ratio of output work to the input energy. Engine efficiency is calculated by various performance parameters, such as Indicated Thermal Efficiency, Brake Thermal Efficiency, Mechanical Efficiency, Volumetric Efficiency, Relative Efficiency etc.

5.2 INDICATED THERMAL EFFICIENCY

It is the ratio of energy in the indicated power ip, to the input fuel energy in appropriate units.

Efficiency = ip[kJ/s]/energy in fuel per sec [kJ/s]

= ip[kJ/s]/(mass of fuel/s x calorific value of fuel)

5.3 BRAKE THERMAL EFFICIENCY

Brake thermal efficiency is the ratio of energy in the brake power, bp, to the input energy in appropriate units.

Efficiency = bp/(mass of fuel/s x calorific value of fuel)

5.4 MECHANICAL EFFICIENCY

Mechanical efficiency is defined as the ratio of brake power (delivered power) to the indicated power (power provided to the piston).

Fp = ip-bp

5.5 SPECIFIC FUEL CONSUMPTION

The fuel consumption characteristic of an engine are generally expressed in terms of specific fuel consumption in kilograms of fuel per kilowatt-hour. It reflects how good is the engine running or performing. It is inversely proportional to the thermal efficiency of engine.

Sfc = Fuel consumption per unit time/ Power

5.6 EFFICIENCY OF ELECTRIC DRIVE

Efficiency = (Output power/Input power)

$$= (T*w/V_{dc} I_{dc})$$

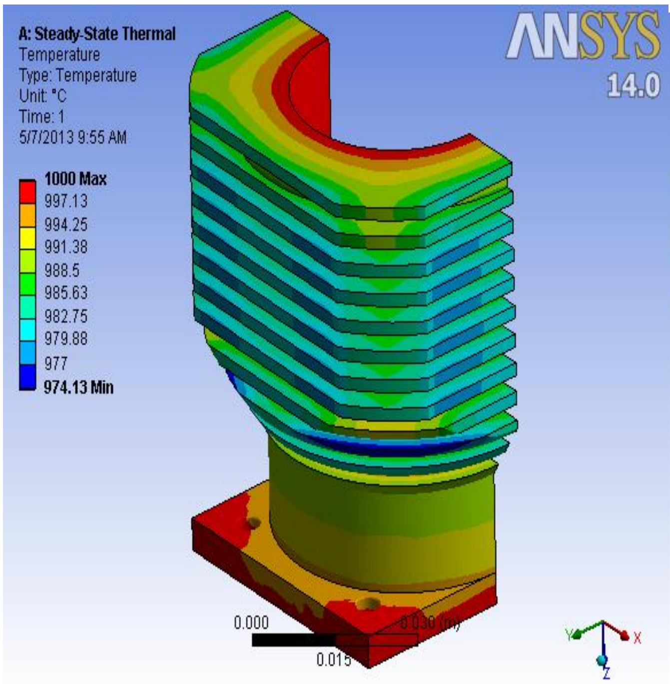
Thus through the expressions efficiency of the vehicle is calculated. The efficiency of IC engine at low speed is very less,i.e, it is less than even 25%. Whereas at this speed the efficiency of battery based drive is almost hundred percent. At high speeds both of them have the same efficiency as both of them are propelled by gasoline energy. Thus from the above discussions it can be concluded that hybrid electric vehicle is more efficient than normal vehicle based on gasoline power source.

CHAPTER **6**

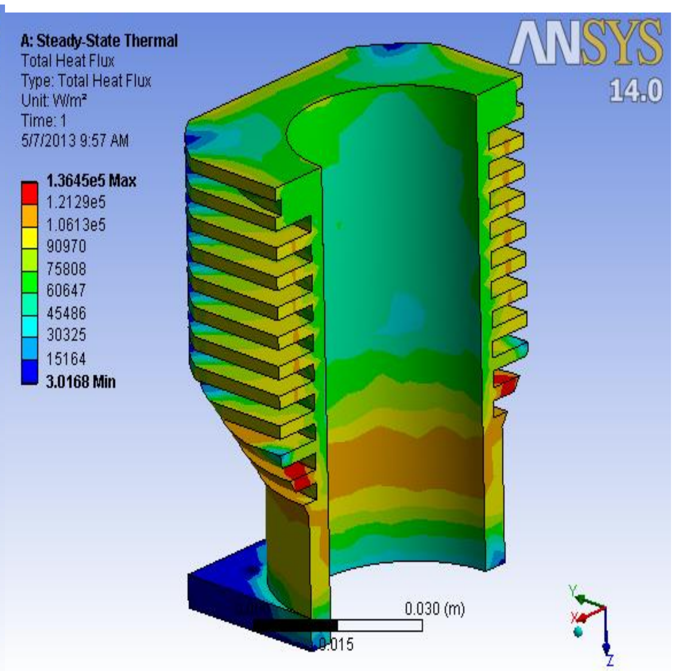
Experimental Results

6.1 ANALYSIS

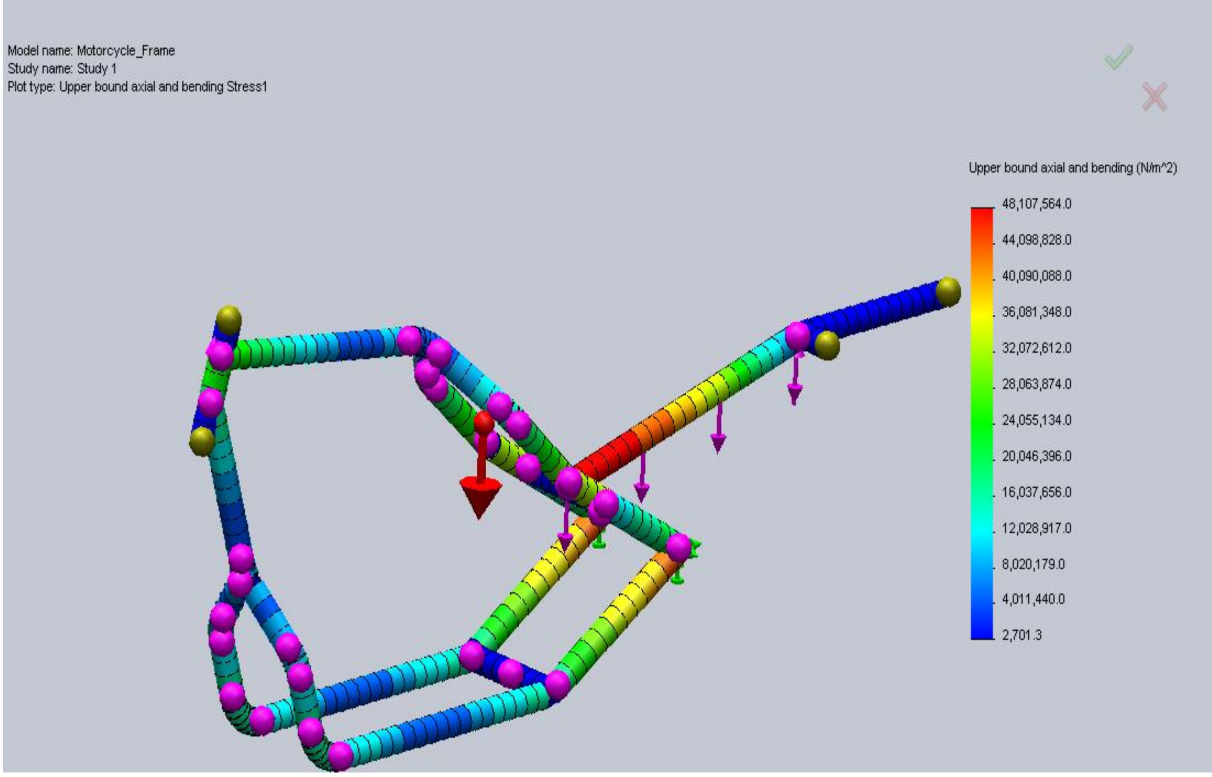
During combustion of gasoline, high temperature gases are generated which increase the temperature of the cylinder head. A long, conductive radiating fins are casted with the cylinder head to remove the heat from the interior to the environment. High temperature affects the performance of the engine, combustion of the lubricating oil is a serious problem which needs to be taken care of. Fig. 6.1 shows the temperature distribution of the cylinder head when the vehicle is running at higher speeds and heat transfer is mainly through convection. The simulation is colour coded which depicts that red colour shows higher temperature and blue colour shows the region of lower temperature. Fig. 6.2 shows the heat flux distribution in a cylinder head. Fig 6.3 shows the stress analysis of the the chassis. The bluish portions experience less stress and the reddish portions have more stress. The chassis portion with red in colour is to be made with proper care. Fig 6.4 shows the inverter output of the electric vehicle. The square wave produced is fed to the BLDC motor for maximum efficiency. Fig 6.5 shows the variation of torque, speed, output voltage and armature current with time of the electric drive.



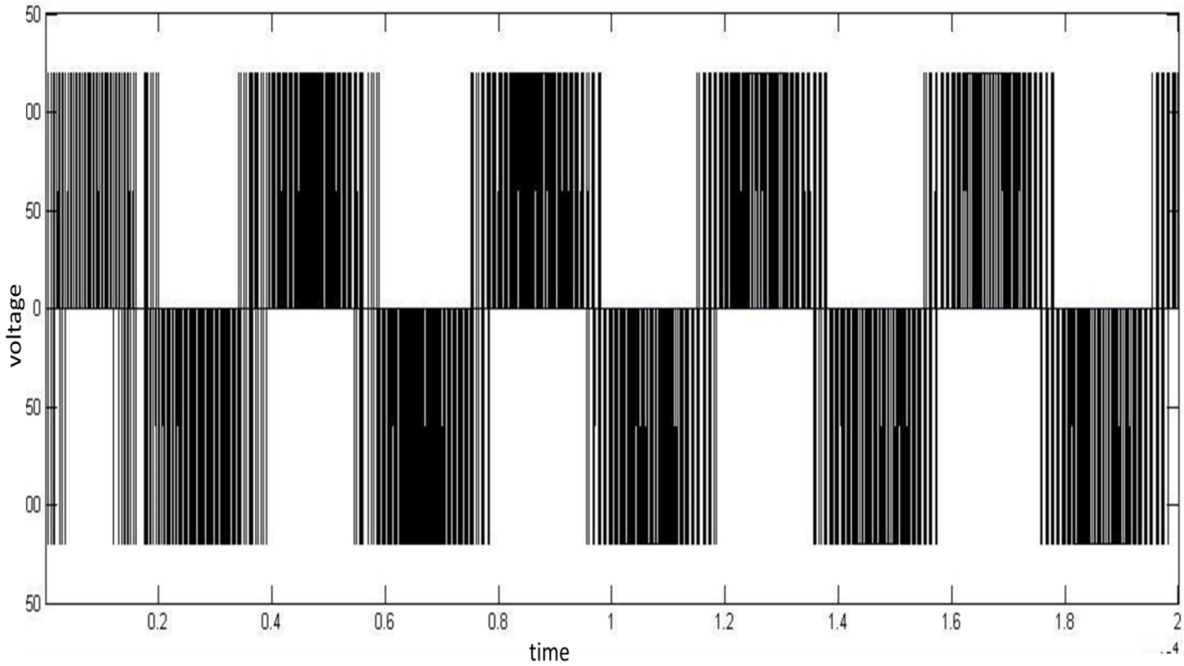
6.1 Temperature Distribution of Cylinder Head



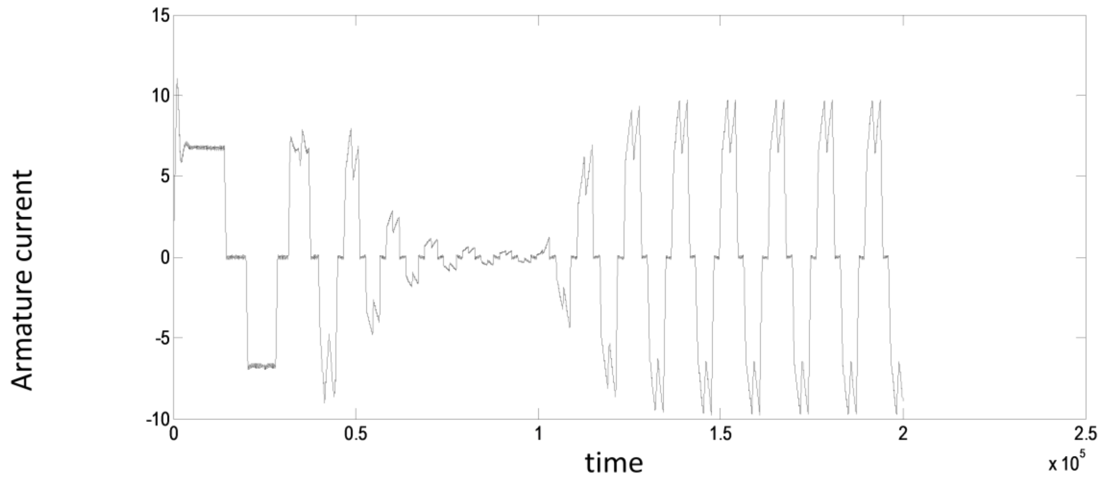
6.2 Heat Flux Distribution in a Cylinder



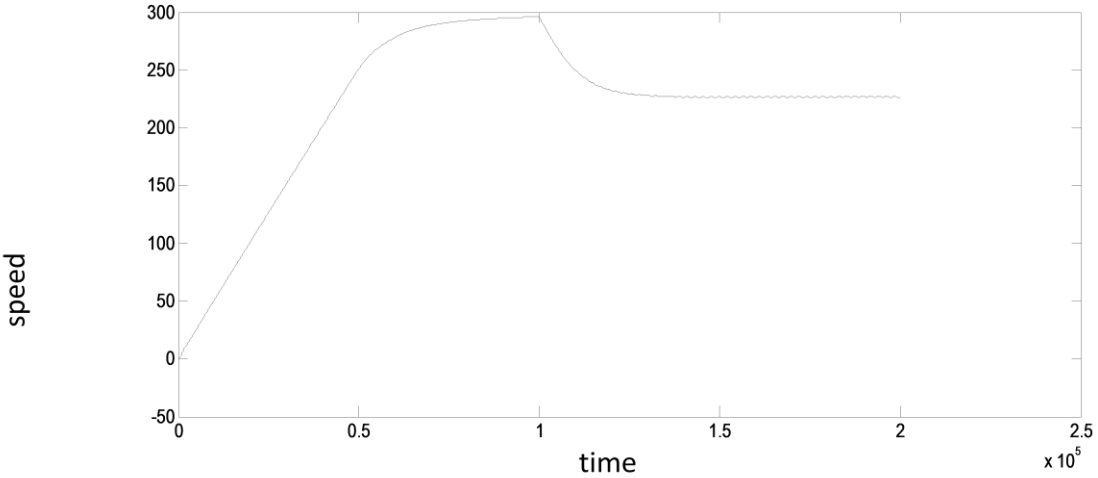
6.3 Stress analysis of chassis



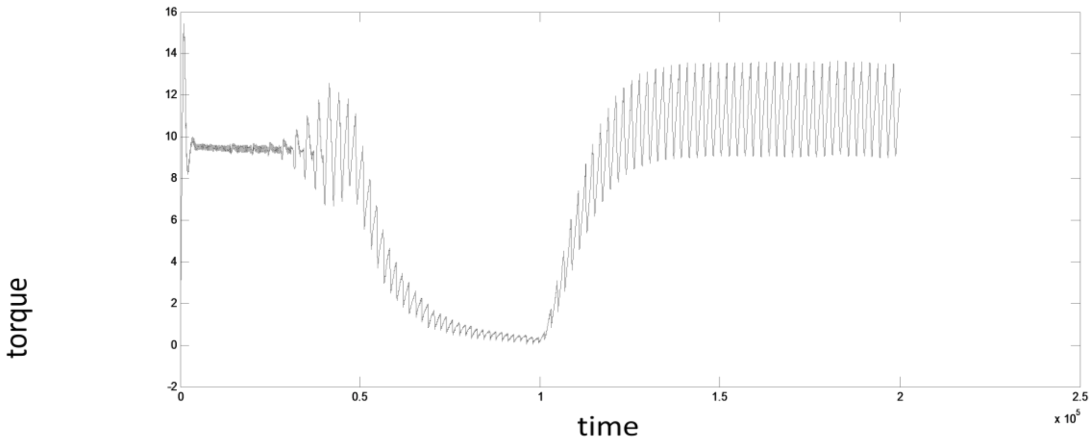
6.4 Output of inverter circuit



6.5 Armature current of electric drive circuit



6.6 Speed of BLDC motor at no load



6.7 Output torque of BLDC motor at no load

6.8 Side view of real time model of two-wheeler HEV

6.9 Front view of real time model of two-wheeler HEV

6.10 Battery based drive circuit for HEV

CHAPTER 7

Conclusion

7.1 CONCLUSION

HEV is a vehicle that uses two sources of power- gasoline and battery. For low power application battery drive is used whereas for high power application where power requirement is very high gasoline engine is used. Gasoline drive is most efficient at high speed drive. Thus HEV's both mode of operation occurs at their maximum efficiency. But in gasoline engine low speed operation is not efficient. Its high speed mode is only efficient. Therefore, it gives twice the mileage given by a normal vehicle. As this hybrid vehicle emits 50% less emission than normal vehicle it plays an important role for reducing pollution to certain extent without compromising with efficiency. Thus it is most efficient in urban areas mainly in high traffic where gasoline engines are least efficient as the energy from gasoline is being wasted away and creates pollution.

7.2 CONTRIBUTON OF THE PROJECT

The current society mostly depends on petroleum as the major source power for vehicle propulsion. The electric vehicle is not very efficient for all power conditions, i.e, it cannot provide power for high speed conditions. Through the project a hybrid method of both the vehicles is proposed which utilises the efficiency of both the vehicles. This method is implemented in two-wheeled vehicles that are mostly preferred by public. Thus proper manufacturing and cost analysis can make the vehicle a major breakthrough.

7.3 FUTURE WORK

The future work deals with finding ways to charge battery automatically without using electricity. The idea is to use that energy which is lost in the exhaust and cooling of the engines. According to Sankey Diagram for gasoline engines only 25% of fuel energy is converted to useful work and rest is rejected into the atmosphere. Nearly 40% energy is wasted in exhaust and 30% as coolant. To convert this unused energy a stirling engine and an array of thermocouple can be used which converts heat into mechanical energy.

To implement the stirling engine concept an exhaust pipe can be connected to one of the hot cylinders of stirling engine, the cold cylinder is exposed to the atmosphere. The heat difference created drives the stirling engine. The stirling engine is connected to dynamo. As the stirling engine rotates through dynamo electric power is produced used to charge the battery.

Thermocouple based electric generation can be done by connecting thermocouples in a parallel array. They are thermally coupled to the cylinder head. The electric output is connected the electric storage recharging circuit. Mechanical energy will be converted to electrical energy by generator and this will be used to recharge the batteries. This concept has never been used in any vehicle worldwide or in India. Theoretically we can achieve twice the mileage with the same fuel consumption and reduce the carbon emission to 50%.

REFERENCES

[1] Resources magazine publication.Replacing Oil: Alternative Fuels and Technologies http://www.rff.org/Publications/Resources/Pages/Replacing-Oil.aspx

[2] Oil depletion analysis centre. ODAC Newsletter - 6 July 2012.http://www.odac-info.org/newsletter/2012/07/06

[3] M. J. Riezenman, "Electric vehicles," IEEE Spectrum, pp. 18–101, Nov.1992.

[4] H. Shimizu, J. Harada, C. Bland, K. Kawakami, and C. Lam, "Advanced concepts in electric vehicle design," IEEE Trans. Ind. Electron., vol. 44, pp. 14–18, Oct. 1997.

[5] C. D. S. Tuck, Ed., Modern Battery Technology. Harwood, p. 411, 1991.

[6] M. Terashima, T. Ashikaga, T. Mizuno, and K. Natori, "Novel motors and controllers for high-performance electric vehicle with four in-wheel motors," IEEE Trans. Ind. Electron., vol. 44, pp. 28–38, Feb. 1997.

[7] R. Prabhakar, S. J. Citron, and R. E. Goodson."Optimization of Automobile Engine Fuel Economy and Emissions." ASME Paper 75-WAlAut-19, Dec. 1975.

[8] J. A. Cook and B. K. Powell. "Discrete Simplified External Linearization and Analytical Comparison of IC Engine Families," Proc. 1987Amer. Conrr. Con$, vol.1, pp. 326-330, June 1987.

[9] V. Wouk, "Hybrids: Then and now," IEEE Spectrum, pp. 16–21, July 1995.

[10] C. Kricke and S. Hagel, "A hybrid electric vehicle simulation model for component design and energy management optimization," in Proc. FISITA World Automotive Congress, Paris, France, Sept. 1998.

[11] M. Ehsani, K. M. Rahman, and H. A. Toliyat, "Propulsion system design of electric and hybrid vehicles," IEEE Trans. Ind. Electron., vol. 44, pp. 19–27, Feb. 1997.

APPENDIX

Equipments used:

IC Engine

SI Engine			Justification
	Stroke	4-stroke	4 stroke engines have better efficiency and this engine commercially cheaper than other engines.
	No of Cylinders	Single Cylinder	
	Displacement	100c	
	Cooling	Air Cooled	
	Fuel Supply	Carburetor	
	Available Models	Kinetic Nova, Honda Activa, Pep	
Power Train			Its automation is much simpler than geared transmission.
	Transmission	Variomatic (CVT)	
	Availability	Comes with engine	

Electric Motor

BLDC Hub Motor			Justification
	Operating Voltage	48Volts	High efficiency and better load carrying capability.
	Power	750 watts	
	Max RPM	380 rpm	
	Max Current	15 amps	
Battery			High discharge capability
	Voltage	48volts	
	Capacity	15Ah	

Accessories

Tyre		
	Front	3.5x10
	Rear	3.5x10
Brakes	Front	130 mm Drum
	Rear	130 mm Drum
Suspension		
	Front	Bottom link with spring loaded hydraulic damper, 80mm travel
	Rear	Unit Swing with spring loaded hydraulic damper, 75mm travel
Clutch	Dry automatic	Centrifugal
Microcontroller	Atmega	1250

Servo Motor	PWM Controlled	15kg/cm
RPM Sensor	Hall Effect Sensor	5v operating voltage
Stirling Engine		
Electronics	Varo Board, Wires, transistors, etc	

Fabrication:

Component	Percentage Manufactured (Company made)	Percentage Fabricated in workshop
Engine	100%	-
Transmission	100%	-
Chassis	50%	50%
Hub motor	100%	-
Stirling Engine	100%	-
Suspension	100%	-
Tyre	100%	-
Motor Controller	0%	100%
Power Control System	0%	100%
Assembly of components	0%	100%
Analysis System	0%	100%