

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

# Design and Implementation of Electric Hybrid Vehicle

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**ABSTRACT :** Hybrid vehicle which is introduced here 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. Also BLDC motor also installed to control the speed.

**KEY WORDS:** HEV powered by battery & gasoline, Regenerative braking, BLDC to control the speed.

### I. INTRODUCTION

In a typical DC motor, there are permanent magnets on the outside and a spinning armature on the inside. The permanent magnets are stationary, so they are called the stator. The armature rotates, so it is called the rotor. The armature contains an electromagnet. When you run electricity into this electromagnet, it creates a magnetic field in the armature that attracts and repels the magnets in the stator. So the armature spins through 180 degrees. To keep it spinning, you have to change the poles of the electromagnet. The brushes handle this change in polarity. They make contact with two spinning electrodes attached to the armature and flip the magnetic polarity of the electromagnet as it spins. This setup works and is simple and cheap to manufacture, but it has a lot of problems such as,

1. The brushes eventually wear out.
2. The brushes limit the maximum speed of the motor.
3. The use of brushes puts a limit on how many poles the armature can have.
4. Because the brushes are breaking connections, you get sparking and electrical noise.

To avoid those problems, BLDC motor is used. Brushless DC electric motor (BLDC motors, BL motors) also known as electronically commutated motors (ECMs, EC motors) are synchronous motors that are powered by a DC electric source via an integrated inverter/switching power supply, which produces an AC electric signal to drive the motor.

“PSO based pid controller for BLDC Motor”, International Journal of Innovative Research In Science, Engineering And Technology, ISSN: 2319-8753, Vol.3, Issue 12, December 2014, S.Rathika And Dr.C.S.Ravichandran. The BLDC motor performance can be controlled and improved by using controller. The PID controller is the most common method in most applications for stability improvement. The controller parameters used

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to improve the step response as well as performance characteristics of BLDC Motor. The conventional methods need manual tuning of PID parameters to improve the performance characteristics. Especially PSO algorithm is used to tune and to get optimal gain values of PID iteratively to control the performance of BLDC motor. In this project, conventional PID controller parameters tuning method is compared with the proposed method. The design and analysis of the PSO based PID controller is simulated using MATLAB. The results obtained from simulation show the significant improvement in the performance.

“Particle swarm optimization based direct torque control of BLDC motor”, international journal of advanced research in electrical, electronics and instrumentation engineering, ISSN: 2320-3765, vol. 3, issue 12, december 2014, Dr.T.Vamsee kiran, and A.Siva nagaraju. This paper deals with the Direct Torque Control (DTC) of BLDC motor drives by using PSO technique. BLDC motors have wide variety of advantages like higher speed ranges, higher efficiency, etc. In DTC, the estimated flux magnitude and torque are compared with their reference values. The reference torque is generated from the output of the speed regulator. Tuning PI parameters ( $K_p$ ,  $K_i$ ) are essential to DTC system to improve the performance of the system at low speeds. In conventional PI controller, the performance of the motor may cause unexpected torque disturbances. Particle swarm optimization (PSO) is proposed to adjust the parameters ( $K_p$ ,  $K_i$ ) of the speed controller in order to minimize torque ripple, flux ripple, and stator current distortion. The simulation results of BLDC drive employing conventional PI and PSO based PI controllers is compared and evaluated under various load disturbances in the MATLAB/simulink environment.

“Modelling and simulation analysis of the brushless dc motor by using MATLAB”, International Journal of Innovative Technology and Exploring Engineering (IJITEE), ISSN: 2278-3075, vol.1, issue 5, october 2012, G.Prasad, N.Sree ramya, P.V.N. Prasad, G.Tulasi ram das. The paper presents a model of three phase star connected brushless dc motor considering the behaviour of motor during commutation. This process is done in MATLAB/ SIMULINK after development of the BLDC motor with sinusoidal and trapezoidal waveforms of back-EMF. A comparison study is presented between the MATLAB/ SIMULINK models of sinusoidal and trapezoidal models of back-EMF.

“Speed control of brushless dc motor with dsp controller using Matlab”, International Journal of Engineering Research and Applications (IJERA), ISSN: 2248-9622, vol.2, issue 3, may-2012, G.Prasad, Venkateswara reddy M, Dr.P.V.N.Prasad, Dr.G.Tulasi ram das. The paper proposes the development of BLDC motor characteristics using a digital signal processor (DSP) motion control kit (MCK28335 kit) compare real results with simulation results. Comparison of real results with simulation results of BLDC motor using MCK28335 kit has been verified. Hence, DSP motion control technique is one of the most efficient and reliable technique that can be applied to control the parameters of the brushless dc motor.

## II. CONSTRUCTION AND WORKING PRINCIPLE

### 2.1 BLDC MOTOR

Brushless DC electric motor (BLDC motors, BL motors) also known as electronically commutated motors (ECMs, EC motors) are synchronous motors that are powered by a DC electric source via an integrated inverter/switching. Power supply, which produces an AC electric signal to drive the motor. In this context, AC, alternating current, does not imply a sinusoidal waveform, but rather a bi-directional current with no restriction on waveform. Additional sensors and electronics control the inverter output amplitude and waveform (and therefore percent of DC bus usage/efficiency) and frequency (i.e. rotor speed). The rotor part of a brushless motor is often a permanent magnet synchronous motor, but can also be a switched reluctance motor, or induction motor. Brushless motors may be described as stepper motors; however, the term stepper motor tends to be used for motors that are designed specifically to be operated in a mode where they are frequently stopped with the rotor in a defined angular position.

### 2.2 CONSTRUCTION OF BLDC MOTOR

Basically, BLDC motor consists of two main parts, namely stator and rotor. Stator is the part that has three phase windings, which is stationary. Rotor is the part which rotates and is connected to the load and to the shaft. The conversion of electrical power to mechanical power takes place in the rotor.

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## 2.2.1 Stator

There are three classifications of the BLDC motor: single phase, two phase and three phase. The single phase and three phase motors are most widely used. A single phase motor has one stator winding which is wound either clockwise or anticlockwise along the arm of the stator to produce four magnetic poles. In similar manner, a three phase motor has three windings and each phase turns on sequentially to make the rotor revolve. There are two types of stator windings: sinusoidal and trapezoidal, which refers to the shape of the back electromotive force (BEMF) signal. The shape of the BEMF is determined by the different coil connections and the distance of the air gap. In addition to the BEMF, the phase current also follows a trapezoidal and sinusoidal shape. A sinusoidal motor produces smoother electromagnetic torque than a trapezoidal motor, though at a higher cost due to their use of extra copper windings.

## 2.2.2 Rotor

A rotor consists of a shaft and a hub with permanent magnets arranged to form between two to eight pole pairs that alternate between north and south poles. There are multiple magnet materials such as ferrous mixtures and rare earth alloys. Ferrite magnets are traditional and relatively inexpensive, though rare- earth alloy magnets are becoming increasingly popular because of their high magnetic density. The higher density helps to shrink rotors while maintaining high relative torque when compared to similar ferrite magnets.

## 2.2.3 Speed Control

An electronic speed control or ESC is an electronic circuit with the purpose to vary an electric motor's speed, its direction and possibly also to act as a dynamic brake. An ESC (Electronic *Speed Control*) is a device that controls the speed of the motor by turning the motor on and off. The controller 'merely' varies the voltage applied to the motor. If you suddenly switch the battery to the motor there is a high initial surge current. If the motor ever tried to take this high current, even for an instant during starting it would instantly blow the controller, so the controller needs to be protected against this. If you want the controller to reverse the motor, then there is reverse polarity protection, protection against operator misuse, regenerative braking, safe response in case of broken wires etc. ESCs are often used on electrically powered radio controlled models, with the variety most often used for brushless DC motors essentially providing an electronically generated three-phase electric power low voltage source of energy for the motor.

The controller works by switching the battery connection to the motor on and off around 20,000 times a second. The motor averages this out, as this rate of switching is too fast for the motor to detect. If the battery is only connected for half the total time, then the motor sees the 24v battery as if it were only 12v, and goes at half speed. Also, because the switching is so fast, the motor's inductance - which acts like an electrical flywheel - keeps the current in the motor flowing constantly. But that current is only flowing for half the time from the battery, so the battery current will be half the motor current.

## III. DESCRIPTION

### 3.1 PROPOSED MODEL

The following are the components which are helpful in achieving the speed control for the BLDC motor.

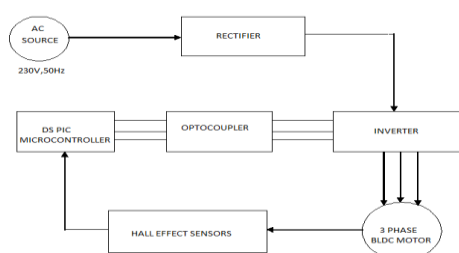


Fig 4.1 Speed Control diagram of BLDC motor

Power Rating	180W
No. of Poles	4
No. of Phases	3
Type of connection	Star
Vdc	36 V
Resistance/Ph	$\Omega$
flux linkages constant	0.105wb
Self Inductance	2.72mH
Mutual inductance	1.5mH
Moment of Inertia	0.000284 kg-m/sec <sup>2</sup>
Damping constant	0.02 N-m/rad/sec

Table 4.1 BLDC motor specifications

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## 3.1.1 POWER SUPPLY

Starting with an AC voltage, a steady DC voltage is obtained by rectifying the AC voltage, then filtering to a DC level, and finally, regulating to obtain a desired fixed DC voltage. The regulation is usually obtained from an IC voltage regulator unit, which takes a DC voltage and provides a somewhat lower DC voltage, which remains the same even if the input DC voltage varies, or the output load connected to the DC voltage changes.

## 3.1.2 TRANSFORMER

The potential transformer will step down the supply voltage (0-230V) to (0-6V) level. Then the secondary of the potential transformer will be connected to the precision rectifier, which is constructed with the help of op-amp. The advantages of using a precision rectifier are it will give a peak voltage output as DC; the rest of the circuits will give only RMS output.

## 3.1.3 BRIDGE RECTIFIER

When four diodes are connected as shown in the figure, the circuit is called as a bridge rectifier. The input to the circuit is applied to the diagonally opposite corners of the network, and the output is taken from other two corners. Let us assume that the transformer is working properly and there is a positive potential, at point A and a negative potential at point B. The positive potential at point A will forward bias D3 and reverse bias D4. The negative potential at point B will forward bias D1 and reverse D2. At this time the D3 and D1 are forward biased and will allow current flow to pass through them; D4 and D2 are reverse biased and will block current flow. The path for current flow is from point B through D1, up through RL, through D3, through the secondary of the transformer back to point B. One-half cycle later the polarity across the secondary of the transformer reverse, forward biasing D2 and D4 and reverse biasing D1 and D3. The current flow will now be from point A through D4, up through RL, through D2, through the secondary of T1, and back to point A. The current flow through RL is always in the same direction. Since current flows through the load (RL) during both half cycles of the applied voltage, this bridge rectifier is a full-wave rectifier. One advantage of a bridge rectifier over a conventional full-wave rectifier is that with a given transformer the bridge rectifier produces a voltage output that is nearly twice that of the conventional full-wave circuit.

## 3.1.4 INVERTER

A power inverter, or inverter, is an electronic device or circuitry that changes direct current (DC) to alternating current (AC). The input voltage, output voltage and frequency, and overall power handling depend on the design of the specific device or circuitry. The inverter does not produce any power; the power is provided by the DC source. A power inverter can be entirely electronic or may be a combination of mechanical effects and electronic circuitry.

## 3.1.5 HALL EFFECT SENSOR

A Hall Effect sensor is a transducer that varies its output voltage in response to a magnetic field. Hall Effect sensors are used for the purpose of positioning, speed detection, and current sensing applications. In its simplest form, the sensor operates as an analog transducer, directly returning a voltage. With a known magnetic field, its distance from the Hall plate can be determined. Using groups of sensors, the relative position of the magnet can be deduced. Frequently, a Hall sensor is combined with circuitry that allows the device to act in a digital (on/off) mode, and may be called a switch in this configuration. Commonly seen in industrial applications such as the pictured pneumatic cylinder, they are also used in consumer equipment; for example some computer printers use them to detect missing paper and open covers. When high reliability is required, they are used in keyboards. Hall sensors are commonly used to time the speed of the wheels such as for internal combustion engine ignition timing, tachometers and anti-lock braking systems. They are used in BLDC motors to detect the position of the permanent magnet. In the pictured wheel with two equally spaced magnets, the voltage from the sensor will peak twice for each revolution. This arrangement is commonly used to regulate the speed of disk drives.

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ELECTRICAL DEGREE	HALL 1	HALL 2	HALL 3
0-60	1	0	1
60-120	0	0	1
120-180	0	1	1
180-240	0	1	0
240-300	1	1	0
300-360	1	0	0

Table 4.2 Hall Effect signal values according to the electrical degree of rotor

## 3.1.5:1 MATERIAL FOR HALL EFFECT SENSOR

The key factor deciding on sensitivity of Hall Effect sensors is high electron mobility. As a result following materials are especially suitable for Hall Effect sensors:

1. Gallium Arsenide (GaAs)
2. Indium Arsenide (InAs)
3. Indium Phosphide (InP)
4. Indium Antimonide (InSb)

## 3.1.6 DSPIC MICROCONTROLLER

### 3.1.6.1 Modules of DSP board

#### 1. TMS320C/F2xx core CPU

It includes a 32 bit central arithmetic unit, a 32 bit accumulator, a 16-bit x 16-bit parallel multiplier with a 32-bit product capability and eight 16-bit auxiliary registers with a dedicated arithmetic unit for indirect addressing of data memory.

#### 2. Memory

It has 64K words program memory space, 64K words data memory space, 64K I/O space.

#### 3. Speed

It takes 25-ns (40MIPS) instruction cycle time, with most instruction single cycle.

#### 4. Watchdog Timer

It is to bring the CPU to reset in case of a fault that causes either CPU disruption or the execution of an improper loop.

1. Dual 10-bit analog- to –digital converter (ADC)
2. 40 individually programmable multiplexed I/O pins
3. Phase-locked loop (PLL) based clock module
4. Serial peripheral interface (SPI)

## 3.1.7 OPTOCOUPLER

In electronics an opto-isolator, also called an optocoupler, photocoupler, or optical isolator, is a component that transfers electrical signals between two isolated circuits by using light. Opto-isolators prevent high voltage from affecting the system receiving the signal. Commercially available opto-isolators withstand input-to-output voltages up to 10 kV and voltage transients with speeds up to 10 kV/ $\mu$ s. In this project, we make use of TLP350 optocoupler.

A common type of opto-isolator consists of an LED and a phototransistor in the same opaque package. Other types of source-sensor combinations include LED-photodiode, LED-LASCR, and lamp-photo resistor pairs. Usually opto-isolators transfer digital (on-off) signals, but some techniques allow them to be used with analog signals.

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## 3.1.7.1 Operation

An opto-isolator contains a source (emitter) of light, almost always a near infrared light-emitting diode (LED), that converts electrical input signal into light, a closed optical channel (also called dielectrical channel), and a photo sensor, which detects incoming light and either generates electric energy directly, or modulates electric current flowing from an external power supply. The sensor can be a photo resistor, a photodiode, a phototransistor, a silicon-controlled rectifier (SCR) or triac. Because LEDs can sense light in addition to emitting it, construction of symmetrical, bidirectional opto-isolators is possible. An optocoupled solid state relay contains a photodiode opto-isolator which drives a power switch, usually a complementary pair of MOSFETs. A slotted optical switch contains a source of light and a sensor, but its optical channel is open, allowing modulation of light by external objects obstructing the path of light or reflecting light into the sensor.

## IV . SIMULATION RESULTS

### 4.1 SIMULATION USING MATLAB

This figure depicts the simulation diagram of the MATLAB for the control of BLDC motor. In this the supply is fed to the MOSFET which is fed to the BLDC motor. From the BLDC motor, the output is acquired and is fed to the demultiplexer. From the demultiplexer, the output is provided to different scopes. The scope1 produces the output waveform of stator line voltage and stator line current. The scope2 produces the output waveform of the rotor speed and torque of the motor. The scope3 depicts the waveform of the 3 Hall Effect sensors.

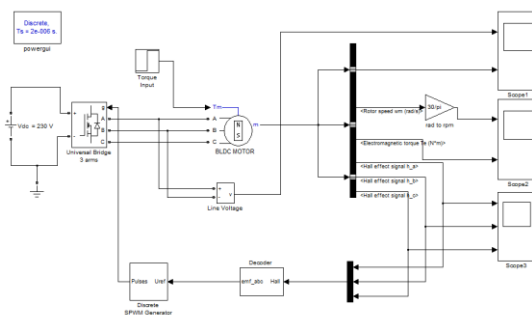


Fig 4.1 Simulation of BLDC motor showing Hall sensor signals

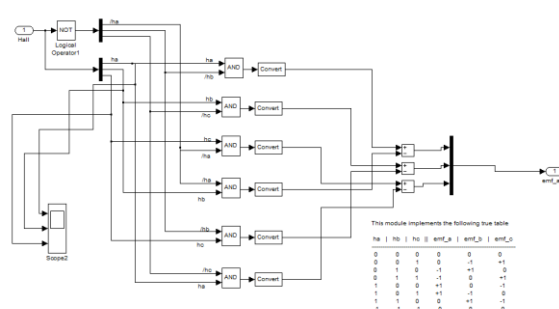


Fig 4.2 Decoder Simulation Diagram

From the BLDC motor the signal is passed on to the bus selector. This block accepts a bus as input which can be created from a block that defines its output using a bus object. The Hall Effect signals are passed on to the decoder where the pulse gets converted to the analog reference voltage and is then passed onto the pulse generator. It is because we can't give pulses directly to the pulse generator since the required voltage can't fit within the limit. The pulses from the pulse generator are applied to the gate of the inverter.

The decoder block in the simulation window1 converts pulses of the Hall Effect sensors to analog voltage. Depending upon the combination of ha, hb and hc, the analog reference voltage applied to the pulse generator varies.

### 4.2 LINE VOLTAGE AND CURRENT WAVEFORMS

The following figure represents the stator line voltage and stator line current values with respect to time. The output of the inverter is pulsating AC which is provided to the stator winding of the motor for the operation of the motor. The presence of large harmonics at the starting stage of the stator line current waveform shows that the settling time taken for the stator line current to reach a stable value is quite small of about 0.025s.



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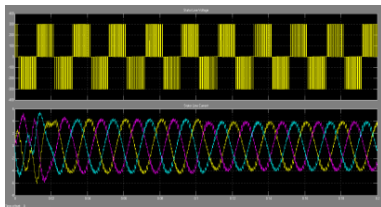


Fig 4.3 Line Voltage and Line Current

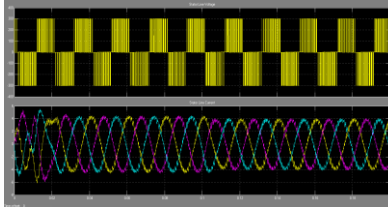


Fig 4.4 Rotor Speed and Torque

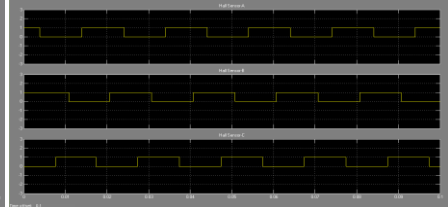


Fig 4.5 Hall Sensor Signal

## 4.3 ROTOR SPEED AND TORQUE WAVEFORMS

This waveform shows the rotor speed with respect to time and the torque obtained with respect to time.

## 4.4 HALL EFFECT SIGNAL WAVEFORMS

The following waveform gives an idea of Hall sensor signals which is mainly used for the purpose of sensing the rotor positions. Each sensor gives a signal and each of the signals has an angular difference of 60°. The three signals are passed on to 3 pins of microcontroller.

## V. HARDWARE REALIZATION

### 5.1 CIRCUIT DIAGRAM

The AC source is connected to a step down transformer which is connected to a bridge rectifier that converts AC to DC. The voltage is passed to the inverter circuit which converts DC to AC and is then passed to the BLDC motor. The BLDC motor is connected to the Hall Sensors which senses the position of the rotor and gives its pulses to a set of pins in the microcontroller. According to the signals, the gate pulses of the 6 inverter switches are provided by 6 optocouplers that will change the motor speed.

### 5.2 INVERTER CIRCUIT

An inverter circuit is designed for conversion from DC to AC. The inverter circuit is designed by making use of 6 switches and the design depend on specific parameters such as the input voltage, output voltage and frequency.

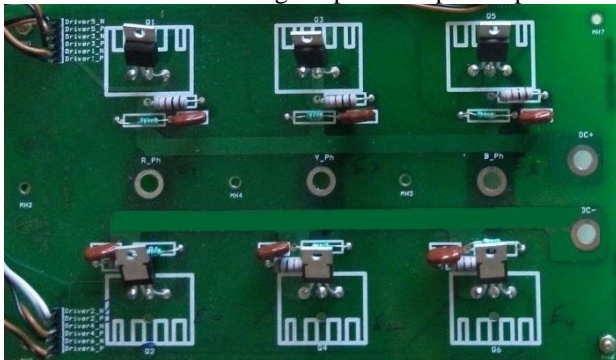


Fig 6.2 Inverter circuit showing 6 MOSFETs



Fig 6.3 Two optocoupler circuit in a single PCB

### 5.3 OPTOCOUPLER CIRCUIT

The voltage from the microcontroller is passed on to the diode, which when passes through the diode the led on the opposite side glows producing a respective gate signal to each switch present in the inverter circuit. In this manner, the gate signal is produced for the 6 switches of the inverter circuit by making use of 6 optocoupler circuit.

### 5.4 DSPIC MICROCONTROLLER CIRCUIT

The DSPIC microcontroller is interfaced in the 28 pin slot is clearly shown in the figure.

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Fig 6.4 Circuit to be interfaced with dsPIC microcontroller



Fig 6.5 Complete controller circuit

## VI. CONCLUSION

Thus, the speed control of Brushless DC (BLDC) motor is achieved by means of PSO algorithm whose applications can be found in Hybrid Electric Vehicle (HEV). PSO has been used for approaches that can be used across a wide range of applications, as well as for precise applications focused on specific requirement. Hence, PSO algorithm is one of the most efficient and reliable technique that can be applied to control the parameters of the Brushless DC motor. This project is done with the help of PIC30F2010.

This project shows that BLDC motor is a good choice in automotive industry due to higher efficiency, higher power density and higher speed ranges compared to other motor types. The DSPIC30F2010 is used to pass the gate signals to the 6 switches of the inverter circuit which in turn is used to control the speed of the Brushless DC (BLDC) motor.

In the near future, we are trying to achieve such speed control without the use of Hall Effect sensors in BLDC motors

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