Design & Performance Evaluation of an Electric Vehicle with Brushless Dc Motor

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Abstract : The main aim of this work is to evaluate the possibility of implementing the conversion of usage of existing fuel vehicles to pollution free electric vehicles by replacing mechanically driven and fuel ignited engine with an electric motor. Here we have studied about employing the design and control of a Brushless DC (BLDC) motor, Supported by a controller unit which proportionately brings in a control over the parameters namely speed of rotation along with the charge.

The Brushless DC motor here is driven by means of a DC electrical energy supplied from battery source which is in turn made to work in tandem with a charge controller to work on the quantity of charge to be acquired or dissipated.

Moreover, to control the speed of the vehicle we take the help of a gear mechanism for making both forward and reverse directions possible for the rotation of the wheels. Drum type brakes are employed for effective braking mechanism

An overview of the various components used and the technique employed for design & performance evaluation of an electric vehicle with brushless DC motor has been presented in this paper

***IndexTerms* - Electric Vehicle, Brushless DC, Motor performance.**

I. INTRODUCTION

Basically the option of designing an electrical vehicle is explored to ensure that the environment is kept fresh to the extent possible even if there are no 100% chances of curbing the utilization of fossil fuels that release of harmful gases that have been contributing to the ever increasing pollution across the globe.

Such a vehicle that relies mainly on the electrical means of initiating the rotation in place of burning a fuel mainly has the following five parts: BLDC motor, Speed Controller, Charger, Accelerator and Battery. The motor controller whose basic function is to control the operation of motor is essentially a microcontroller based system that uses feedback to control a three-phase BLDC motor. A three phase motor consists of permanent rotor and a stator split into three phases. Three phase motor are used because they are efficient, durable and deliver constant power throughout each cycle.

The motor is driven by means electrical energy supplied from battery source which is later given to BLDC motor by using charge controller.

Moreover, the speed of the vehicle is controlled with the help of a gear mechanism for moving in both forward and reverse directions of the wheels. Drum type brakes are employed for effective braking mechanism

II. BLOCK DIAGRAM & COMPONENTS

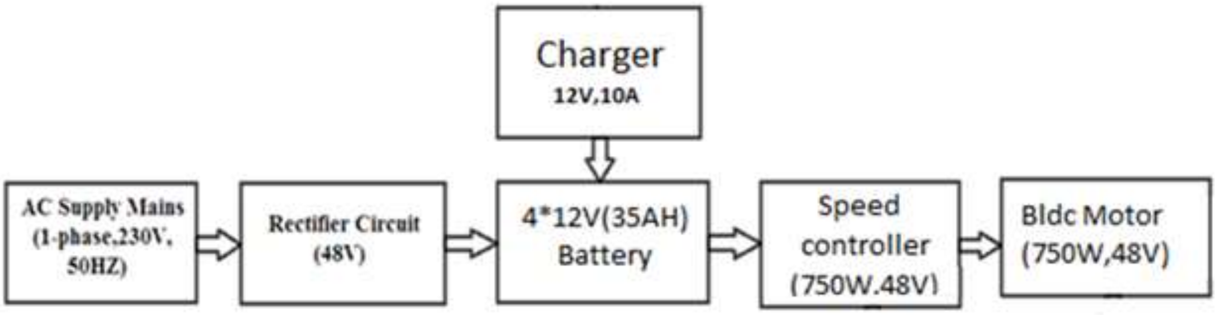


Figure 1: Block Diagram

The block diagram of a BLDC motor driven Electric vehicle consists of a speed controller; rectifier circuit, battery, BLDC Motor, and AC supply mains. The charger used for electrical vehicle is of 12V, 10A. The rectifier being an electrical conversion device converts alternating current (AC) whose direction reverses periodically in to direct current (DC), which flows in only one direction.

The batteries used here are of 48V contributed by four units each of 12V output and a current of 35A. The type of batteries using are lead-acid batteries. Speed controller rating is of 48V and 750W. BLDC Motor used is rated at 48V and 750W. The supply taken from AC mains is 1-ph 230V, 50Hz.

III.CONSTRUCTION DIAGRAM

Construction diagram connects the speed controller, accelerator, charger, motor and hall sensor terminals explaining the operation of the system.

The accelerator provided helps the vehicle to run at our desired speed which is the reference speed connected to the logic circuit terminals. The logic circuit consists of the five terminals which are connected to the BLDC Motor out of which the first three terminals are hall sensor terminals and the other two are supply terminals.

The hall sensor which senses the speed of the vehicle also compares the speeds with reference speed and tries to shift the phases during running of the vehicle. The driver circuit consists of three terminals which are connected to the BLDC Motor by means of which shaft is coupled to the gear box of the vehicle to help the smooth running of the vehicle

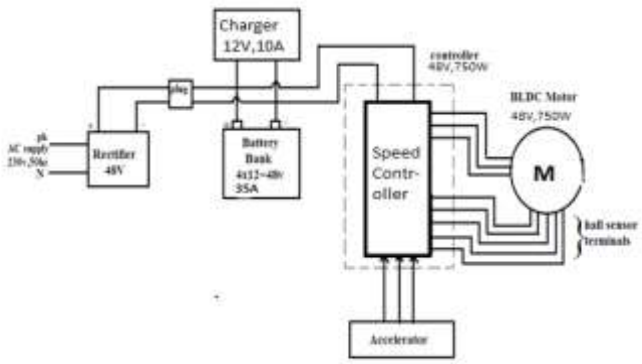


Figure 2: Construction Diagram

IV. BLDC MOTOR

Figure 3: BLDC Motor

The accelerator provided helps the vehicle to run at our desired speed which is the reference speed connected to the logic circuit terminals. The logic circuit consists of the five terminals which are connected to the BLDC Motor out of which the first three terminals are hall sensor terminals and the other two are supply terminals. The hall sensor which senses the speed of the vehicle also compares the speeds with reference speed

The BLDC motor is actually a permanent magnet AC motor whose torque-speed characteristics mimic the DC motor. Instead of commutating the armature current using brushes, electronic commutation is used. Having the armature on the stator makes it easy to conduct heat away from the windings, and if desired, having cooling arrangement for the armature windings is much easier as compared to a DC motor. A BLDC motor is a modified PMSM with the modification being that the back-emf is trapezoidal instead of being sinusoidal as in the case of PMSM.

The position of the rotor can be sensed by Hall Effect position sensors, namely Hall-A, Hall-B, and Hall-C, each having a phase lag of 120^0 with respect to the earlier one. Three Hall position sensors are used to determine the position of the rotor field. BLDC motor is the choice in many applications requiring precise control of speed. The BLDC motor model is explained as, the electromagnetic torque, T_{em} is linearly proportional to the armature current I_a. i.e., $T_{em}=K_T I_a$, where K_T is the torque constant.

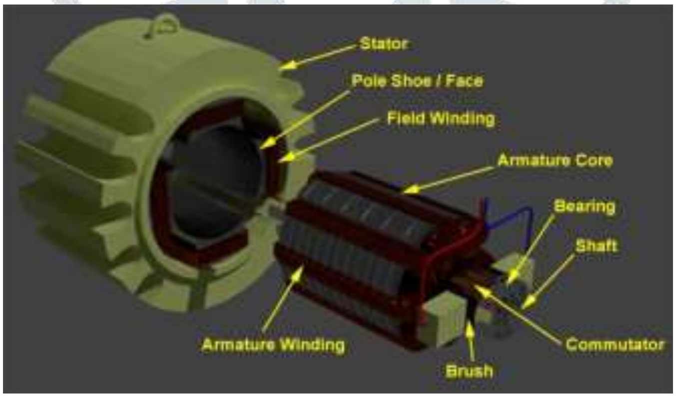


Figure 4: BLDC Motor Parts

A BLDC motor is a permanent magnet BLDC motor that uses position detectors and an inverter to control the armature currents. The BLDC motor is sometimes referred to as an inside out DC motor because its armature is in the stator and the magnets are on the rotor and its operating characteristics resemble those of a DC motor. Instead of using a mechanical commutator as in the conventional DC motor, the BLDC motor employs electronic commutation which makes it a virtually maintenance-free motor.

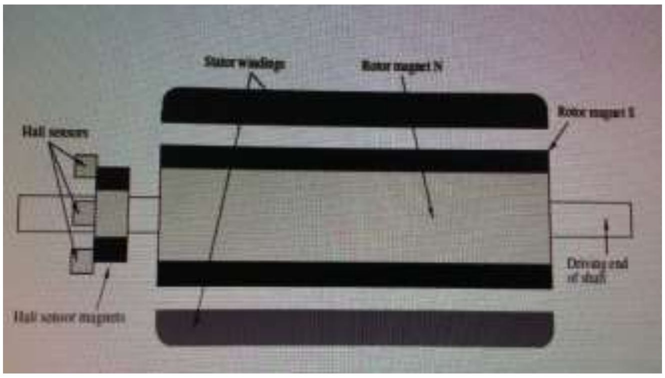


Figure 5: Working of a BLDC Motor

Hall Sensor

These hall sensors are placed every 120^0. With these sensors, 6 different commutations are possible. Phase commutation depends on hall sensor values. Power supply to the coils changes when hall sensor values change. With right synchronized commutations, the torque remains nearly constant and high.

Working Principle of a BLDC Motor:

The principle of working for a BLDC motor is same as in a brushed DC motor; i.e., internal shaft position feedback. In case of a brushed DC motor, feedback is implemented using a mechanical commutator and brushes. With a in BLDC motor, it is achieved using multiple feedback sensors. The most commonly used sensors are hall sensors and optical encoders.

Hall sensors work on the hall-effect principle that when a current-carrying conductor is exposed to the magnetic field, charge carriers experience a force based on the voltage developed across the two sides of the conductor.

If the direction of the magnetic field is reversed, the voltage developed will reverse as well. For Hall-effect sensors used in BLDC motors, whenever rotor magnetic poles (N or S) pass near the hall sensor, they generate a HIGH or LOW level signal, which can be used to determine shaft.

In a commutation system – one that is based on the position of the motor identified using feedback sensors – two of the three electrical windings are energized at a time.

In figure 4 (A), the GREEN winding labeled "001" is energized as the NORTH pole and the BLUE winding labeled as "010" is energized as the SOUTH pole. Because of this excitation, the South Pole of the rotor aligns with the GREEN winding and the North Pole aligns with the RED winding labeled "100". In order to move the rotor, the "RED" and "BLUE" windings are energized in the direction shown in figure 4(B).

This causes the RED winding to become the North Pole and the BLUE winding to become the South Pole. This shifting of the magnetic field in the stator produces torque because of the development of repulsion (Red winding – NORTH-NORTH alignment) and attraction forces (BLUE winding – NORTH-SOUTH alignment), which moves the rotor in the clockwise direction.

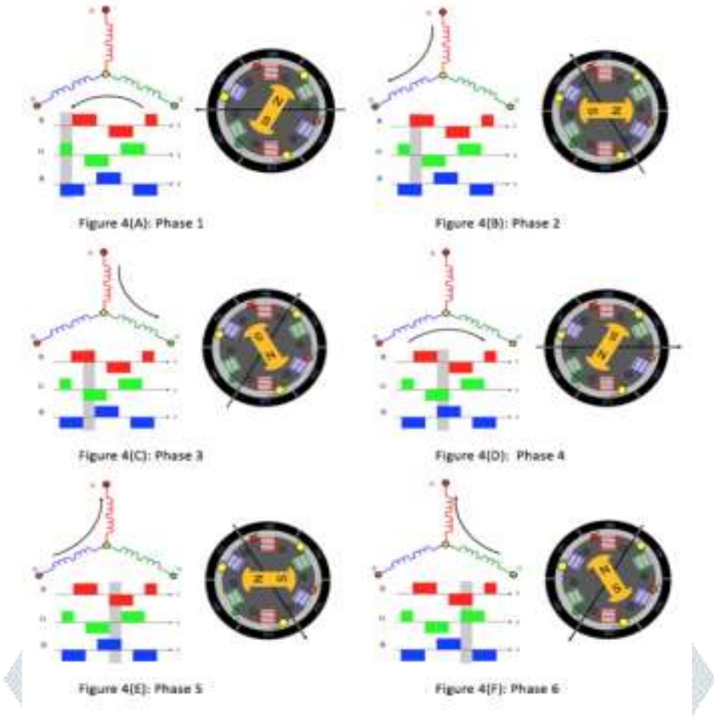


Figure 6: Phase operation of BLDC Motor

Advantages of BLDC motor over DC motor

Performance: The dynamic accuracy of the BLDC motor is very high. Dynamic accuracy means the machine performs consistently, with the same efficiency.

Size: Thus the machine occupies lesser floor space, weighs lighter and hence it makes handling of the machine easier.

Efficiency: The BLDC motor is the most efficient motor available in the present industry.

Running Cost: Running cost of the vehicle is very less compared to ignited engines. If we take an example one liter cost of petrol is approx 80 INR it gives mileage of nearly 60 kms. In electric vehicle it takes nearly 10 INR for full charge of the battery which approx gives 55 to 60 kms mileage and tries to shift the phases during running of the vehicle.

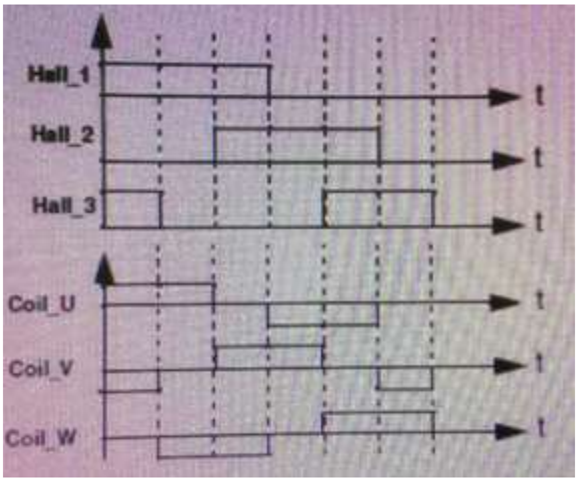


Figure 7: Torque and Efficiency

For the study of electric motors, torque is a very important term. By definition, torque is the tendency of force to rotate an object about its axis.

$$Torque\ (Newton - meters) = Force\ (Newton)\ X\ Distance\ (meters)$$

Thus, to increase the torque, either force has to be increased – which requires stronger magnets or more current – or distance must be increased – for which bigger magnets will be required. Efficiency is critical for motor design because it determines the amount of power consumed. A higher efficiency motor will also require less material to generate the required torque.

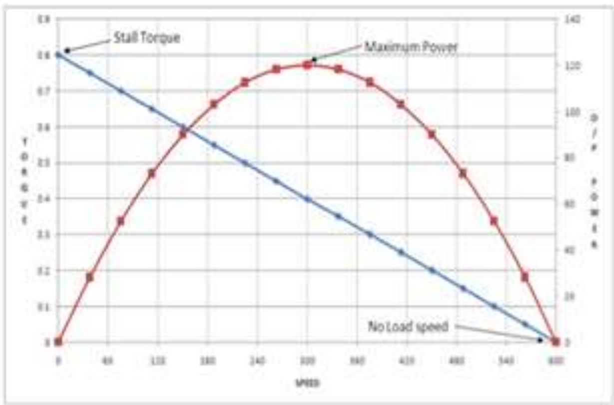
$$Efficiency = \frac{Output\ Power}{Input\ Power}\%$$

Where,

$$Output\ Power = Torque\ X\ Angular\ Velocity, \text{ and}$$

$$Input\ Power = Voltage\ X\ Current$$

Figure 8: Speed vs. torque curve



Following are the takeaways from the graph shown in Figure 5:

- With an increase in speed, the torque reduces (considering the input power is constant).
- Maximum power can be delivered when the speed is half of the “no load” speed and torque is half of the stall torque.

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