# Review Paper on Controllling of BLDC Motor In Electric Vehicle

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***Abstract***- *Growing need for high productivity is placing new demands on mechanisms connected with electrical motors. The demand for low cost Brushless DC (BLDC) motor has increased in industrial applications. This review paper include various controlling technique of bldc motor in electric vehicle. In this review paper following control techniques are discussed and those methods are: Square wave control, Sine wave control, FOC( Field oriented control).*

***Keywords***- BLDC Motor, FOC, BEMF, Hall Sensor, PMSM,

## I. INTRODUCTION

Brushless DC motors (BLDC) are an invaluable part of industry today. Use of these motors can save nearly any industry a great deal of time and money under the right circumstances. The BLDC motor actually represents the end, or at least the most recent end result, of a long evolution of motor technology. Before there were brushless DC motors there were brushed DC motors, which were brought on in part to replace the less efficient AC induction motors that came before. Electric vehicles are at least twice as efficient as conventional vehicles. So we are encouraging more electric vehicles than conventional vehicles. In this system an idea of retrofitting the conventional vehicles to electric vehicles is proposed. A BLDC motor drive and its controller can be designed as per the weight and torque specifications on existing conventional vehicles. This will reduce the cost because existing conventional vehicles are transformed to electric vehicles with required specification. BLDC motor is proposed because it has high torque, high efficiency, reduced noise, easy speed control and longer lifetime. As the name suggests brushless dc motor does not have brushes and they are commuted electronically. BLDC motors are known for their high durability due to simplicity in design and high rpm capabilities. They have both small and large applications. The motor is controlled by a motor controller . The motor controllers need rotor position to control the motor. Some type of controllers use hall effect sensors or rotary encoder to sense the rotor position. Others measure the back emf in the undriven coils to infer the rotor position. It contains three output terminals which are controlled by logic circuits. Advanced controllers use microcontroller to manage acceleration and speed.

## II. MOTOR DESCRIPTION

### A. OPERATING PRINCIPLE

BLDC motors are a type of synchronous motor. This means the magnetic field generated by the stator and the magnetic fields generated by the rotor rotate at the same frequency. BLDC motors do not experience the “slip” that is normally seen in induction motors. BLDC motors come in single-phase, 2-phase and 3-phase configurations. Corresponding to its type, the stator has the same number of windings. Out of these, 3- phase motors are the most popular and widely used. This application note focuses on 3- phase motors. The brushless motor, unlike the DC brushed motor, has the permanent magnets glued on the rotor. It has usually four magnets around the perimeter. The stator of the motor is composed by the electromagnets, usually four of them, placed in a cross pattern with 90° angle between them. The major advantage of the brushless motors is 4 that, due to the fact that the rotor carries only the permanent magnets, no need of winding connections to be done with the rotor, no brush-commutator pair needs to be made. This is how the brushless motors took their name from.

*Fig- BLDC motor*

**B. WORKING**

Before explaining the working of a brushless DC motor, it is better to understand the function of a brushed motor. In brushes motors, there are permanent magnets on the outside and a spinning armature which contains electromagnet is inside. These electromagnets create a magnetic field in the armature when the power is switched on and help to rotate the armature. The brushes change the polarity of the pole to keep the rotation on of the armature. The basic working principle for the brushed DC motor and for brushless DC motor are same i.e. internal shaft position feedback. Brushless DC motor has only two basic parts: rotor and the stator. The rotor is the rotating part and has rotor magnets whereas stator is the stationary part and contains stator windings. In BLDC permanent magnets are attached in the rotor and move the electromagnets to the stator. The high power transistors are used to activate electromagnets for the shaft turns. The controller performs power distribution by using a solid-state circuit.

**C. COMPONENT DESCRIPTION:**

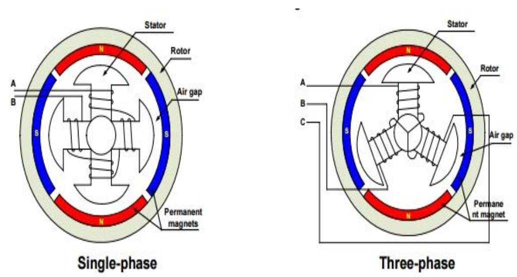
- STATOR
- ROTOR

**STATOR:**

There are three classifications of the BLDC motor: single-phase, two-phase and three-phase. This discussion assumes that the stator for each type has the same number of windings. The single-phase and three-phase motors are the most widely used. Figure 5 shows the simplified cross section of a single-phase and a three-phase BLDC motor. The rotor has permanent magnets to form 2 magnetic pole pairs, and surrounds the stator, which has the windings. There are two types of stator windings: trapezoidal and sinusoidal, which refers to the shape of the back electromotive force (BEMF) signal. The shape of the BEMF is determined by different coil interconnections 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. A BLDC motor uses a simplified structure with trapezoidal stator windings.

**ROTOR:**

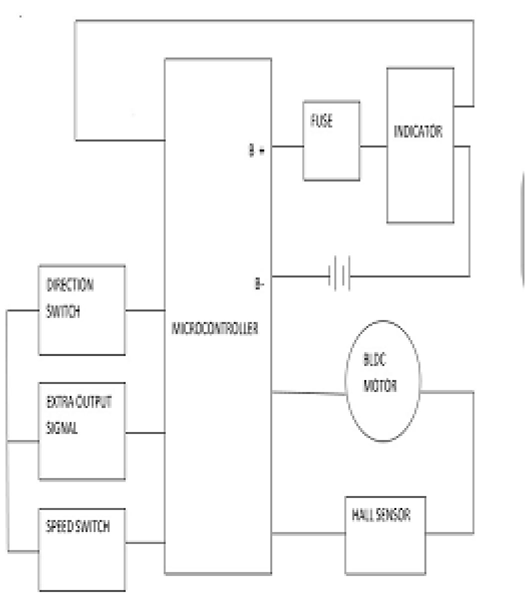
A rotor consists of a shaft and a hub with permanent magnets arranged to form between two to eight pole pairs that alternate between north and south poles. Figure 6 shows cross sections of three kinds of magnets arrangements in a rotor. There are multiple magnet materials, such as ferrous mixtures and 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.




## III. CONTROLLING TECHNIQUE OF BLDC MOTOR

The block diagram of BLDC drive system is shown in Figure. It consists of a three phase inverter, position sensors, signal conditioner and a digital controller. The inverter along with the position sensor arrangement is functionally analogous to the commutator of a dc motor. Karnataka 1666 Vol.3 Issue 5, May – 2014 International Journal of Engineering Research & Technology (IJERT) International Journal of Engineering Research & Technology (IJERT). The commutation of a BLDC motor is controlled electronically. The stator windings should be energized in a sequence in order to rotate the motor. Rotor position should be known in order to switch the winding in sequence.

A permanent magnet brushless dc motor incorporates some means of detecting the rotor position. The BDLC motor detects the position of the rotor using Hall sensors.Three sensors are required for position information.With three sensors, six possible commutation sequences could be obtained. In the Hall sensor technique, three Hall sensors are placed inside the motor, spaced 120 degrees apart. Each Hall sensor provides either a High or Low output based on the polarity of magnetic pole close to it. Rotor position is determined by analyzing the outputs of all three Hall sensors.




Based on the output from hall sensors, the voltages to the motor's three phases are switched. The advantage of Hall sensor-based commutation is that the control algorithm is simple and easy to understand.Hall sensor-based commutation can also be used to run the motor at very low speeds. BLDC motor control is to have only one current at a time. Because of which current sensor is not advised to be placed on each phase of the motor; one sensor placed in the line inverter input is sufficient to control the current of each phase. Insulated systems are not required when sensor is on the ground line. The torque and speed of motors is managed by microcontroller. A sufficient amount of processing power is required to solve the algorithms needed to generate Pulse Width Modulated (PWM) outputs for motor. By simply varying the voltage across the motor, one can control the speed of the motor. When using PWM outputs to control the six switches of the three-phase bridge, variation of the motor voltage can be achieved easily by changing the duty cycle of the PWM signal. The three-phase BLDC speed control is done by using both open loop and closed loop configurations. Open-loop control is used to control the speed of the motor by directly controlling the duty cycle of the PWM signal that directs the motor-drive circuitry. The duty cycle of the PWM signal controls the ON time of the power switches in the half bridges of the motor-drive circuit and this in turn controls the average voltage supplied across the motor windings. Closed loop control regulates the speed of the motor by directly controlling the duty cycle of the PWM signals that direct the motor-drive circuitry. The major difference between the two control systems is that the open-loop control considers only the speed control input to update the PWM duty cycle, whereas, the closed-loop control considers both speed-input control and actual motor speed (feedback to controller) for updating the PWM duty cycle and, in turn, the motor speed. A PID controller is a closed-loop control implementation that is widely used and is most commonly used as a feedback controller. The actual motor speed is calculated by tracking the time period between successive Hall events, which represents a part of the mechanical cycle of the motor. In a 3-phase BLDC motor control, one electrical cycle has six Hall states and, depending on the number of poles pairs in the motor, the electrical angle measured between successive Hall state changes can be translated to a respective mechanical angle.

**A. SQUARE-WAVE CONTROL :**

BLDC motor is a class of Permanent magnet synchronous motor (PMSM). The wave shape of induced emf in PMSM decide types of motor. If induced emf is square/ trapezoidal then motor is square type BLDC motor.

**120° Square wave commutation for BLDC motor**

There are basically two types of commutation techniques :

1. 120° square wave commutation
2. 180° sine-wave commutation

In 120 commutation of BLDC motor, the pattern of commutation is controlled with the help of 3-phase bridge inverter which comprises of 6 switching devices.

In one phase, the high side devices is kept ON, in another phase the low side device is turned ON and the remaining phases of both the high and low side devices are turned OFF.

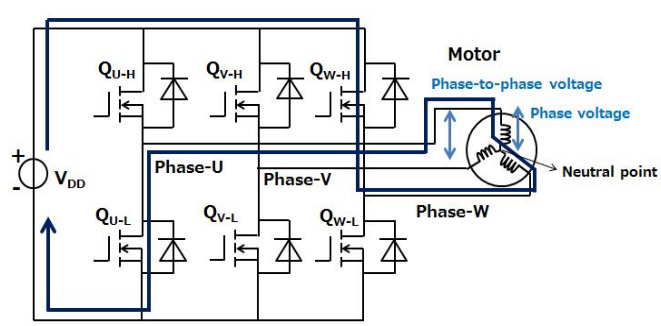



*Fig-120° commutation*

Above fig. shows all phases are connected to power source for 120 electrical degree, off for 60 electrical degree, connected to ground for 120 electrical degree and also off for 60 electrical degree.

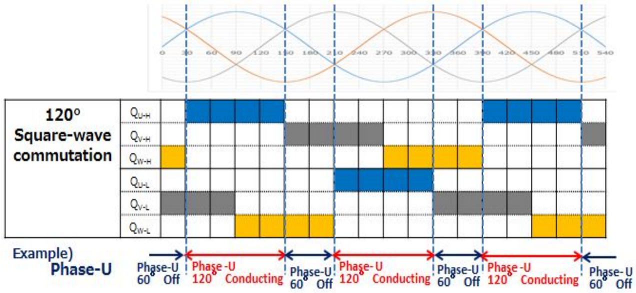
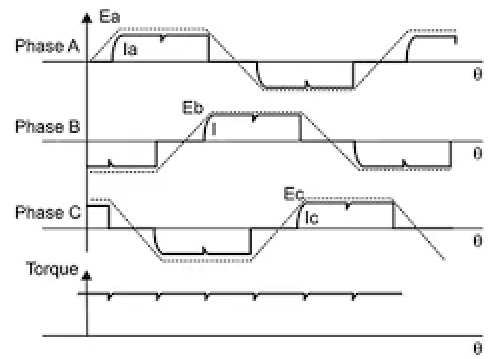



*Fig- Switching of six devices for 120° square-wave commutation*

Square-wave control uses Hall sensor or sensorless estimation algorithm to obtain the position of the motor rotor, and then commutates six times in the 360° electrical cycle according to the position of the rotor (commutate per 60°). The motor outputs a specific direction force at each commutation position, so it can be said that positional accuracy of the square-wave control is electrical 60°. In this control method, the phase current waveform of the motor approaches the square wave, so it is called square-wave control.Advantage of square-wave control include: simple control algorithm, low hardware cost, and higher motor speed can be obtained by using ordinary controller.

**B. SINE -WAVE CONTROL**

The disadvantage of square-wave control include: large torque ripple, a certain current noise, efficiency is not up to the maximum. Square-wave control is suitable for occasions where motor rotation performance and efficiency is not high. So to overcome the disadvantages of Square-wave commutation sine-wave commutation is used. Theoretically back emf waveform is trapezoidal but practically inductance smooths back emf in more sinusoidal shape. It eliminates torque ripple inherent to trapezoidal and provide smooth motion and precise control. Sine-wave commutation is superior to Square-wave commutation in-terms of efficiency, precise control, sine-wave commutation is complex and is higher in cost whereas Square-wave commutation is less complicated. Based on the complexity degree of control, the sine-wave control of brushless DC motor can be divided into: simple sine-wave control and complicated singe-wave control.




**1. Simple sine-wave control:**

The motor winding is exerted with a certain voltage, enabling the phase voltage of the motor to be sine wave. Because the motor winding is the inductive load, the phase current of the motor is sine wave as well. The phase and amplitude of the current is controlled through controlling the amplitude and phase of the motor phase voltage. It is the voltage loop control and has simple realization. The simple sine-wave control means to realize the purpose of controlling the motor current through controlling the amplitude and phase of the sine phase voltage. Generally, the motor end line is exerted with the voltage of a certain form to have sine phase voltage to the two ends of the winding. The common generation means includes: Sine PWM and space vector PWM. Because PWM has simple principle and easy realization, it is usually employed as the PWM generation means in simple sine-wave control.

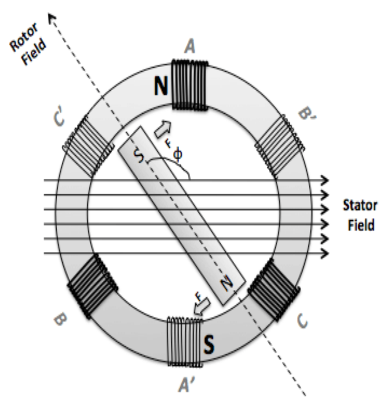
**2. Complicated sine-wave control:**

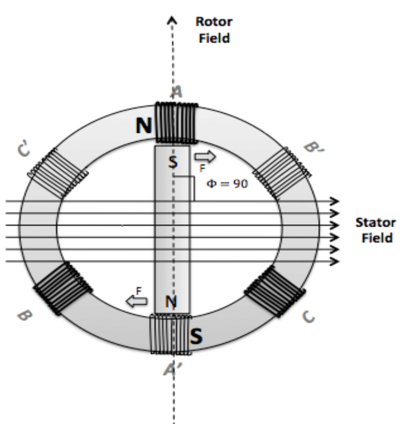
Different from the simple sine-wave control, the purpose of the complicated sine-wave control is the phase current of the motor, and the establishment of the current loop, so as to realize the purpose of controlling the motor through controlling the phase and amplitude of the phase current. Because the phase current of the motor is the sine signal, it is required to conduct the decoupling operation of the current, which is rather complicated. The common ones include field-orientated control (FOC) and direct torque control (DTC) and so on.

Sine wave control uses the SVPWM wave and outputs the three-phase sine-wave voltage, corresponding current is sinusoidal current. In such a control mode, there's no concept of commutation as the square-wave control, nor it thinks that infinite commutations have been occurred in an electric cycle. Obviously, sine wave control has smaller torque ripple and less current harmonics than the square-wave control, its control is more "exquisite". However, it has higher performance requirements for controller than the square-wave control, the motor efficiency can not be maximum.

### C. FOC CONTROL

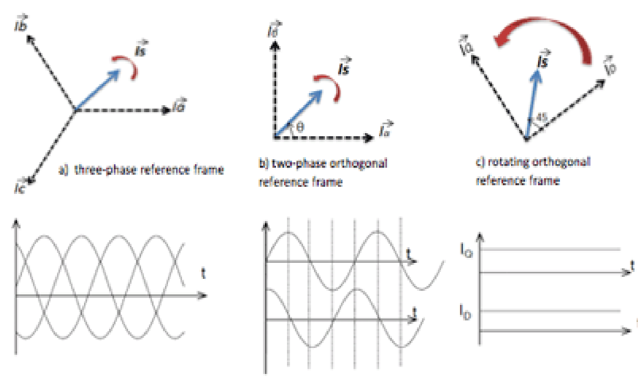
Sine wave control realizes the control of voltage vector and indirectly realizes the current control, but it can not control the direction of current. FOC control can be regarded as an upgraded sine wave control, it realizes the control of current vector, namely realizing the vector control of motor’s stator magnetic field. Field oriented control can be divided into two: direct field oriented control and indirect field oriented control. Direct field orientated control is based on flux vector identification which is determined either by direct measurement or estimation from other parameters. By direct measurement it is meant that there are Hall effect sensors in the air gap between rotor and stator. Indirect field orientated control means that the rotor flux vector is determined indirectly by measuring the mechanical angle of the rotor by a shaft position sensor. This thesis focuses on the indirect variant of the control method.




Field oriented control for BLDC motors has six basic steps as described in.

1. Two phase currents are measured and the third can be calculated using Kirchhof’s current law (KCL).
2. Measured phase currents are converted into a two axis system by using Clarkes transformation.
3. The two axis coordinate system which was generated in the previous step is transformed to align with the rotor magnetic flux by using Park's transformation.
4. Calculated d and q axis currents are used as feedback for PI controllers, where the direct axis current reference value is zero for permanent magnet motor and direct axis current reference is generated from the torque command generated by the speed control loop.
5. The direct and quadrature axis voltages from PI controllers are translated back to the stationary two axis reference frame using inverse Park's transformation.
6. The alpha-beta reference frame values are converted back to the 3-phase quantities and are inputs to the pulse width modulation.




Advantages of FOC control include: small torque ripple, high efficiency, low noise and fast dynamic response. Disadvantages include: high hardware cost, higher requirement for the controller performance, and motor parameters need to be matched. Due to its distinct advantages, FOC control has gradually replaced the traditional control mode in many applications and won great favor in motion control field.

## IV. CONCLUSION

By providing BLDC drive we can achieve smooth operation with high efficiency, high torque and easy speed regulation.From the above discussion it can be seen that Square- wave control have problems related to noise, torque ripple also the efficiency is not upto the maximum. In case of Sine -wave control cost is more and complex. Hence it can be concluded that FOC(field oriented control) is best suited in terms of complexity, efficiency , torque ripple and low noise as compared to Sine-wave and Square-wave control.

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