Volume : 5 | Issue : 1 | JANUARY 2016 • ISSN No 2277 - 8179

Research Paper

Rotor Position Sensing of D.C. Brushless Motors

Engineering

KEYWORDS : Electronic Commutation, Hall sensors , Encoders, Resolvers.

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ABSTRACT

The brushless dc motor requires the position and speed sensors for control. Since the system behaves like a conventional separately excited d.c. motor, the speed can be controlled by the variation of the d.c. supply to the inverter or to the field. The speed is inversely proportional to the field current. The torque-speed characteristics are similar to those of a separately excited d.c. motor but is slightly more drooping in this case.

There are several possible methods of detecting the rotor position, using sensors like Hall elements or optical sensors.

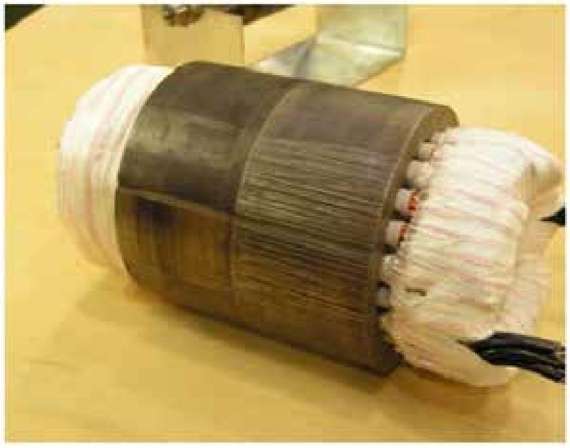
Introduction

In PM d.c. brushless motors the armature current has a shape of a square (trapezoidal) waveform, ***only two phase windings (for Y connection) conduct the current at the same time*** and the switching pattern is synchronized with the rotor angular position **(electronic commutation).**

The armature current of synchronous and d.c. brushless motors is not transmitted through brushes, which are subject to wear and required maintenance. Another ***advantage*** of the brushless motor is the fact that the power loss occur in the stator, where heat transfer conditions are good. Consequently ***the power density*** can be increased as compared with a d.c. commutator motor.

Thus, the volume of a brushless PM motor can be reduced by more than 40% while still keeping the same rating as that of a PM commutator motor**.**

BLDC Stator



The **major difference** between syn. Motor & BLDC motor is that syn. Motor develop a sinusoidal back EMF, as compared to a rectangular or trapezoidal, back EMF for brushless DC motor. Both have stator created rotating magnetic fields producing torque in a magnetic rotor.

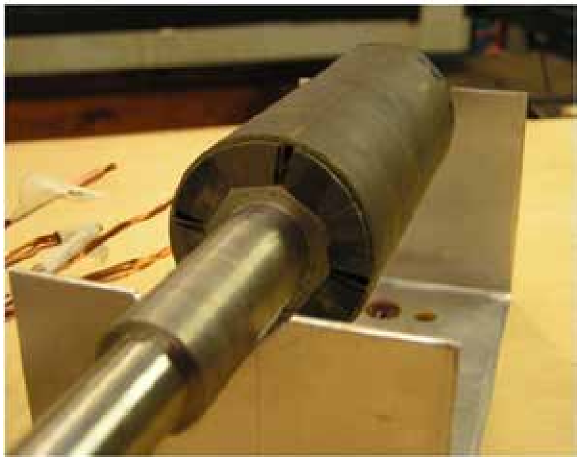
The commutation of a brushless DC motor depends on the position of the rotor. The angle between the magneto-motive forces of stator and rotor is fixed to 90 (el.), so the motor produces maximum torque.

Speed can only be controlled by the motor voltage.

The brushless DC motor needs a rotor position sensor. There are several possible methods of detecting the rotor position, using sensors like Hall elements or optical sensor.

On the other hand there are some possibilities of a sensorless detection of the rotor position, which can be integrated advantageously into a brushless DC motor.

BLDC Rotor and shaft



Electronic Commutation

The static inverter with the shaft positions-sensitive controller can very well be regarded as an electronic commutataor serving the same function as does the mechanical commutator.(Here dc motor compare with ac synchronous motor.)

The stator winding of the commutatorless d.c. motor may be the conventional three-phase winding of a synchronous motor or the conventional armature winding of a d.c. motor. However, in both cases, the stator winding has to be supplied from a static inverter triggered by shaft position sensitive signals so that the supply frequency is proportional to shaft speed. The d.c. field winding is placed on the rotor and supplied from a static d.c. source through slip rings mounted on the motor shaft.

It has already been explained that, the static inverter together with the shaft-position sensitive trigger circuit is equivalent to the mechanical commutator of a d.c. machine.

If the stator winding is ***similar*** to the armature of d.c. machine, six symmetrical tappings from the winding can be taken out and the stator winding may be fed from a six-phase SCR bridge inverter. This is equivalent to six segment commutation. There may be many other variations of the electronic commutation arrangement.

It is, therefore, ***clear*** that a three-phase synchronous motor when fed by a three phase inverter behaves like a simple d.c. motor but the SCRs of the inverter should be triggered in proper sequence and instant proportional to the position of the rotor

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shaft. The SCRs may be turned off naturally owing to the nature of the load which is a synchronous motor.

Since the system ***behaves*** like a conventional separately excited d.c. motor, the speed can be controlled by the variation of the d.c. supply to the inverter or to the field. The speed is inversely proportional to the field current. The torque-speed characteristics are similar to those of a separately excited d.c. motor but is slightly more drooping in this case.

There are several possible methods of detecting the rotor position, using sensors like Hall elements or optical sensors.

III Rotor Position Sensing of d.c. brushless motors

Hall sensors :-

The ***Hall element*** is a magnetic field sensor. When placed in a stationary magnetic field and fed with a d.c. current it generates an output voltage

$VH = kH\ 1/\delta\ Ic\ B\sin\beta$

where kH is Hall constant in m^3/C, δ is semiconductor thicknesss, Ic is the applied current, B is the magnetic flux density and Hall element surface. The polarity depends on whether the pellet is passing a North or a South pole. Thus it can be used as a magnetic flux detector.

Rotor position sensing of three phase d.c. brushless motors requires three Hall element. All necessary components are often fabricated in an integrated chip (IC). For driving a three-phase two-pole motor, the sensors, in principle, should be placed 120˚ apart. However, they can also be placed at 60˚ intervals.

Hall sensors are mounted in such a way that they each generate a ***square wave with 120˚ phase difference***, over one electrical cycle of the motor. The inverter or servo amplifier drives two of the three motor phases with d.c. current during each specific Hall sensor state.

2) Encoders:-

There are ***two types*** of optical encoders:-

Absolute encoders

Incremental encoders.

In ***optical encoders*** a light passes through the transparent areas of a grating and is sensed by a photodetector. To increase the resolution, a collimated light source is used and a mask is placed between the grating and detector. The light is allowed to pass to the detctor only when the transparent sections of the grating and mask are in aligment.

In an ***incremental encoder*** a pulse is generated for a given increment of shaft angular position which is determined by counting the encoder output pulses from a reference. The rotating disk (grating) has a single track. In the case of power failure an incremental encoder loses position information and must be resetto known zero point.

An ***absolute encoder*** is a position verification device that provides unique position information for each shaft angular location. Owing to a certain number of output channels, every shaft angular position is described by its own unique code. The number of channel increase as the required resolution increase. An absolute encoder is not a counting device like an incremental encoder and does not lose position information in the case of loss power.

The disk (made of glass metal) of an absolute encoder has several concentric tracks to which indepent light source are assigned. Multi-turn absolute encoders have additional disks geared to the main high resoiultion disk with step up gear ratio.

3**)** *Resolvers:-*

A resolver is a rotary electromechanical transformer that provides outputs in forms of trigonometric function of its inputs. For detecting the rotor position of brushless motors, the excitation or primary winding is mounted on the resolver rotor and the output or secondary windings are wound at right angles to each other on the stator core. As a result the output signals are sinusoidal waves in quadrature, i.e., one wave is a sinusoidal function of the angular displacement θ and the second wave is a cosinusoidal function of θ.

There is one electrical cycle for each signal for each revolution of the motor. The analog output signals are converted to digital form to be used in a digital positioning system. The difference between the two waves reveals the position of the rotor. The speed of the motor is determined by the period of the waveforms and the direction of rotation is determined by the leading waveform.

Instead of delivering the excitation voltage to the rotor winding by brush and slip rings, an inductive coupling system is frequently used

IV Sensorless motors

There are several reasons to eliminate electromechanical position sensors:-

Cost reduction

Reliability improvement of the system

Temperature limits on Hall sensors

In motors rated below 1W the power cosumption by position sensors can substantially reduce the motor efficiency

In compact applications, e.g., computer hard disk drives, it may not be possible to accommodate position sensors.

Sensorless control strategies are different for PM d.c. brushless motors with trapezoidal EMF waveforms where only two out of three phases are simultaneously excited and PM synchronous motors or motors with sinusoidal EMF waveforms where all three phases are exicted at any instant of time. ***The simplest methods for PM d.c. brushless motors are based on back EMF detection in an unexcited phase winding***. Sensorless controllers measure back EMF signals from the unenergized winding to determine the commutation point.

V CONCLUSIONS

In d.c. brushless motor rotor position sensing by three method. a) Hall Sensor b) Encoders c) Resolvers.

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