Research Paper

Sensorless Motor

Engineering

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ABSTRACT   *The brushless dc motor requires the position and speed sensors for control. However, it is requested to eliminate these sensors from standpoints of size and cost reduction, maintenance and reliability. The approach to the sensorless operation becomes different, depending on the flux distribution. The paper presents the concept sensorless control of the brushless dc motor.*

I.INTRODUCTION:-

A) Electronic Commutation:-

It is known that in a d.c. motor there are stationary electromagnets which supply the magnetic field and an armature having a number of coils distributed over its surface rotates in this magnetic field. The armature coils, of course, are interconnected to form a close winding.

The armature receives current through a mechanical commutator and brushes and torque is produced due to interaction of fields produced by armature and the magnets.

When a commutator segment comes in contact with the brush, current flows through that section of the winding which is connected to the d.c. supply through the brush and commutator segments. Thus the commutator serves the purpose of switching current from one section of the armature winding to the other at the correct instant. Thus a d.c. motor can be thought of as an ac synchronous machine in which the field is stationary and the armature with its multiphase ac winding is rotating. The armature receives ac power from a dc source through brushes and commutators.

The brushes and the commutator constitute an inverter sensitive to the shaft position.

In a similar way, a synchronous motor may be considered to operate as a dc motor. In a synchronous machine the field is rotating whereas the armature is stationary but it should be supplied by an inverter controlled by shaft position-sensitive controller sensing signals.

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.)

This facilitates the operation of the synchronous motor as a versatile-speed drive like a d.c. motor but having no mechanical commutations and brushes. This is no doubt a great advantage. 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 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.

B) Sensorless Motor:-
There are several reasons to eliminate electromechanical position sensors:-
1. Cost reduction
2. Reliability improvement of the system
3. Temperature limits on Hall sensors
4. In motors rated below 1W the power cosumption by position sensors can substantially reduce the motor efficiency
5. 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 excited 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.

II Trend in permanent magnet motors and drives industry:-
The electromechanical drives market analysis shows that the d.c. commutator motor drive sales increase only slightly

each year whilst the demand for a.c. motor drives increases substantially. The same tendency is seen in the brushless PM motor drives as compared with PM d.c. commutator motor drives.

From today's perspective, the Far East (principally Japan, China and South Korea), America and Europe will remain or become the largest market area.

III The parameters of Permanent Magnets:-

Permanent magnets provide a motor with life-long excitation. The only outlay is the initial cost, which is reflected in the price of the motor. Brodaly speaking, the primary determinants of magnet cost are the torque per unit volume of the motor, the operating temperature range, and the severity of the operational duty of the magnet.

a) Power density :-

For maximum power density the product of the electric and magnetic loadings of the motor must be as high as possible. The electric loading is limitef by thermal factors, and also by the demagnetizing effect on the magnet. A high electric loading necessitates a long magnet length in the direction of magnetization, to prevent demagnetization.

It also requires a high coercivity, and this may lead to the more expensive grades of material (such as coblat-samarium), especially if high temperatures will be encountered.

The magnetic loading, or airgap flux, is directly proportional to the remanent flux density of the magnet , and is nearly proportional to its pole face area. A high power density therefore requires the largest possible magnet volume (length times pole area).

With ceramic magnets the limit on the magnet volume is often the geometrical limit on the volume of the rotor itself, and the highest power densities cannot be obtained with these magnets. With rare-earth or other high-energy magnets, the cost of the magnet may be limiting factor.

With a straight demagnetization characteristic throughout the second quadrant and a recoil permeability of unity, the maximum energy-product (BH) max is given by

(BH) max = Br^2 % (4µ∗) j/m³.
b) Operating temperature range :-

Because of degradation in the remanent flux density and in the coercive force, the choice of material and the magnet volume must usually be determined with reference to the highest operating temperature.

Fortunately brushless motors have very low rotor losses. The stator is easily cooled because of the fine slot structure and the proximity of the outside air.Consequently the magnet can run fairly cool (often below 100°C) and it is further protected by its own thermal mass and that of the rest of the motor.

The short-time thermal overload capability of the electronic controller would normally be less than that of the motor, providing a further margin of protection against magnet overtemperature.

c) Severity of operational duty :-

Magnets can be demagnetized by fault currents such as short-circuit currents produced by inverter faults. In brushless motors with electronic control the problem is generally limited by the protective measures taken in the inverter and the control. The design must accommodate all the fac-

tors that stress the magnet, not only electromagnetic but thermal and mechanical as well.

IV Mechanical properties, handling and magnetization:-

Magnets are often brittle and prone to chipping, but proper handling procedures are straightforward enough as long as the rules are followed. Modern high-energy magnets are usually shipped in the magnetized condition , and care must be taken in handling to avoid injury that may be caused by trapped fingers. A further hazard is that when two or more magnets are brought close together they may flip and jump, with consequent risk to eyes.

A very wide range of shapes is possible, but in motors the most common are arcs and sometimes rectangles. Tolerances in the magnetized direction can be held very close, ±0.1 mm even for standard magnets.

Thermal expansion of magnets is usually different in the directions parallel and perpendicular to the magnetic axis. Most magnets have a high comprerssive strength but should never be used in tension or bending.

Ceramic and Alnico magnets can sometimes be magnetized in situ in the final assembly, but this is almost never possible with high-energy magnets.

V CONCLUSIONS

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.

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