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A Research Review on Offline Fem Sensorless Control for BLDC-PM Motor

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Abstract: ***This paper presents the FEM assisted sensorless control for BLDC-PM motor. The sensorless control of BLDC motor is based on the line to line PM flux linkage. The rotor position and speed are obtained by using this FEM method. The position is determined by comparing the line to line PM flux linkage with the FEM calculated PM flux linkage. The reliability of this method for BLDC-PM motor is determined through the simulations and experimental results.***

Keywords: Brushless DC Permanent Magnet (BLDC-PM) motor, Finite Element Method (FEM), Sensorless control..

I. INTRODUCTION

In BLDC-PM motor, sensorless control technique is used to control the speed. The sensorless control is done based on line to line PM flux linkage. By changing the duty cycle and voltage, the speed can be controlled.

II. SENSORLESS CONTROL

The motor is run without position sensor is known as sensorless operation. The control operation with position sensor has several disadvantages like cost, size and noise. The usage of hall position sensors are eliminated by this technique. Sensorless operation can control position and speed without position sensors.

The advantages of sensorless techniques are very robust, wide dynamic and low noise operation. Sensorless technique is used to control the BLDC-PM motor by using a Digital Signal Controller. In BLDC-PM motor, the position error is reduced by the sensorless operations. Two basic classifications to obtain the sensorless control are,

- Indirect Method
  - Back EMF integration technique
  - Back EMF sensing technique
- Direct Method
  - Offline Finite Element Method

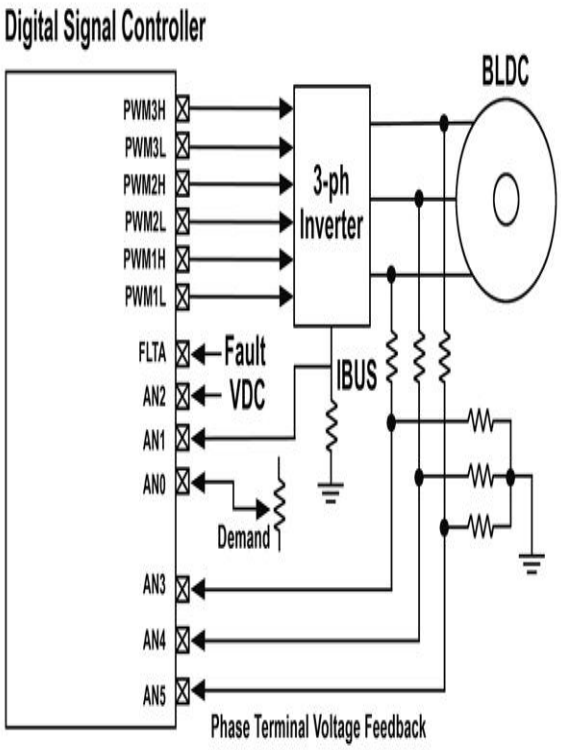

Fig.1. Digital Signal Controller

A. Indirect Method

The rotor position is indirectly estimated by this method. The advantages of this method are easy completion and low computational trouble.

1. Back Emf Integration Technique:

Of the three phases in the drive only two phases performs operation. The EMF of the motor in phase three is a function of position and velocity.

The first two phases of the motor are connected to the dc bus and ground respectively. By measuring the voltage, the back EMF is determined.The back EMF of the motor corrects the velocity and position.

2. Back emf sensing technique:

In this technique, the zero crossing point detection is used to estimate the rotor position indirectly. When back EMF is zero, there are only two positions per electrical cycle is obtained. The speed is greater than zero is determined by zero crossing point detection.

B. Direct Method

The position is estimated by using the FEM method. The advantages are good reliability and reduce error accumulation problems.

1. Offline finite element method:

The rotor position is estimated by line to line PM flux linkage. By the phase current and voltage of the BLDC-PM motor, the line to line PM flux linkage is calculated. The speed of the rotor is determined from the rotor position and electromagnetic torque. By this the sensorless control of the motor is obtained.

III. BLDC-PM MOTOR

BLDC-PM motor has eight rotor poles and 12 nonuniform stator slots. The permanent magnet is placed in the rotor and coils in the stator. Magnetic forces between permanent magnet motor and stator is used to obtain mechanical energy.

The life span of the BLDC-PM motor is about 15000 hours. Three phase inverter is used to drive the BLDC-PM motor. In this machine, two phases are conducting while third phase is opened.

The speed control of the motor can be achieved by varying the voltage. The voltage is directly proportional to the speed. By varying the stator voltage, the motor speed increases. This is achieved by altering the duty cycle of the base PWM signal.

In open loop speed control, the duty cycle is directly calculated from the set reference speed and there is no actual speed feedback for control purpose. In closed loop control, the set speed and actual speed are compared and the error is fed to the PI controller. The speed control of the motor is achieved by the duty cycle obtained from PI controller. The speed can be controlled by measuring the actual speed of the motor.

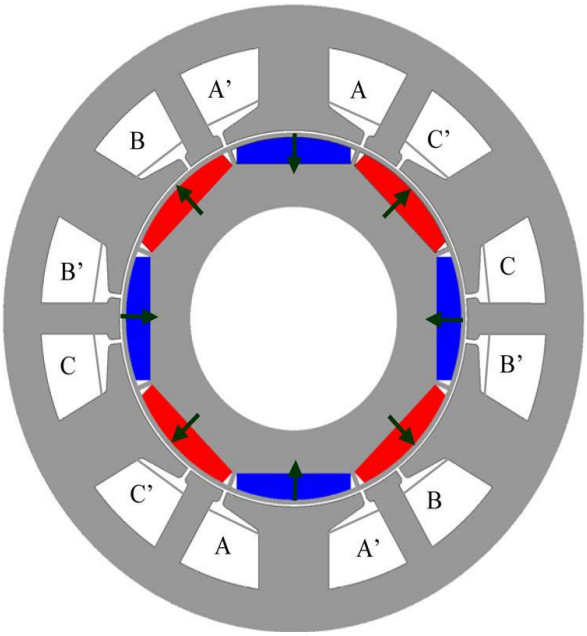

Fig. 2 Cross section of BLDC-PM motor

The speed of BLDC-PM motor can be controlled in Pulse Width Modulation (PWM) scheme. Inverters are also known as dc to ac converters. The three phase inverter has six switches that could be MOSFETs/IGBTs. The input dc is usually obtained from a single phase or three phase utility power supply through a diode bridge rectifier and LC filter or C filter.

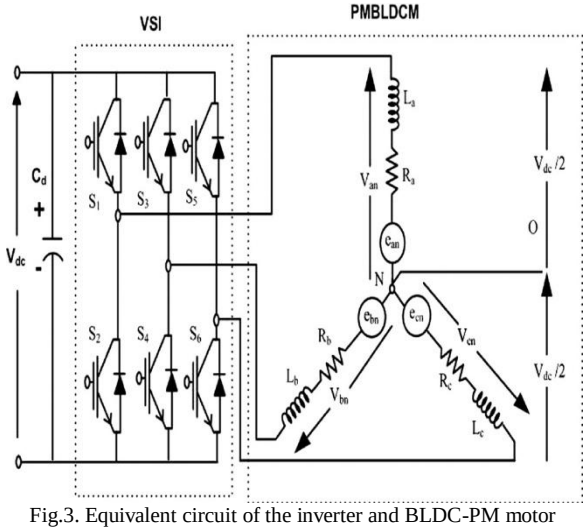

Fig.3. Equivalent circuit of the inverter and BLDC-PM motor

In open loop speed control, the duty cycle is directly calculated from the set reference speed and there is no actual speed feedback for control purpose. In closed loop control, the set speed and actual speed are compared and the error is fed to the PI controller. The speed control of the motor is achieved by the duty cycle obtained from PI controller. The speed can be controlled by measuring the actual speed of the motor.

IV. THREE PHASE INVENTER

Inverters are also known as dc to ac converters. The three phase inverter has six switches that could be MOSFETs/IGBTs. The input dc is usually obtained from a single phase or three phase utility power supply through a diode bridge rectifier and LC filter or C filter.

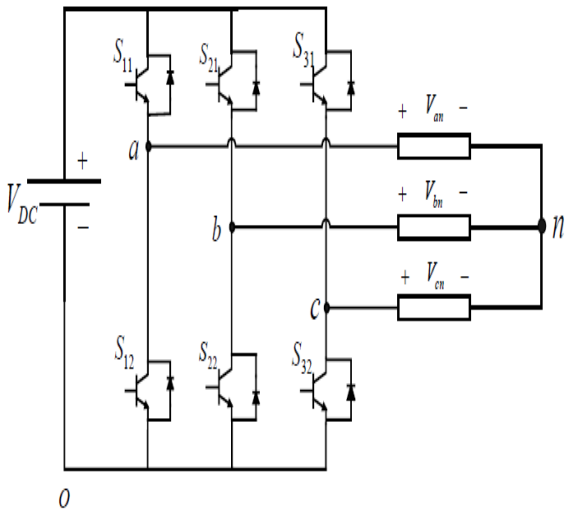

Fig. 4 Three Phase Inverter Circuit diagram

In order to realize the three-phase output from a circuit employing dc as the input voltage a three-phase inverter has to be used.

In this case, the ac line currents freewheel through either the upper or lower components. Line voltages of the three phase inverters are $-V_{DC,}$ 0, and $V_{DC.}$

The single phase voltage source inverters are used for low power applications. In Medium to high power applications three phase voltage source inverters are utilized. Changes in the Inverter switching pattern depends on the Pulse Width Modulation (PWM) scheme.

For carrying reverse currents, anti parallel diodes are connected if IGBTs are used while body diodes are connected if MOSFETs are used. The advantage of MOSFETs over IGBTs is offset voltage drop. Three phase inverters are most commonly used in BLDC motor applications.

V. FINITE ELEMENT METHOD

FEM software is a very powerful tool for the design and analysis of electrical motors. The error in the solution is reduced by using this method. This powerful design tool has significantly improved both the standard of engineering designs and the methodology of the design process in many industrial applications.

FEM simulations can be divided into the following

- Definition of the problem
- Solution of the problem
- Results analysis

A. Definition of the problem

The problem should be analyzed as the first step. The definition of the problem is faced in three steps. They are i)definition of the geometry, ii)creation of mesh, iii)definition of the physical property.

B. Solution of the problem

Iterative methods are used to solve the problems of electric machines.

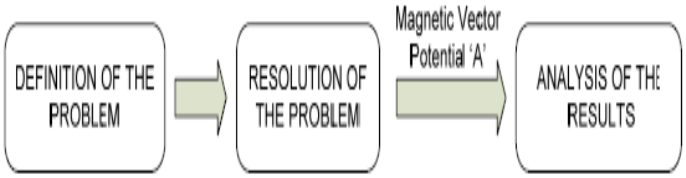

Fig.6. Different strategies in FEM simulations

C. Results analysis

Two popular FEM formulations are Galerkin formulation and Ritz formulation. The derivatives with respect to spatial variables are tackled in the usual way of FEM. The Finite element steps are,

i) Pre processing,

ii) Solution of system equations and

iii) Post processing.

The electromagnetic characteristics are evaluated accurately by FEM analysis. FEM is very useful to calculate the equivalent circuit lumped parameters such as inductance and iron losses resistance. FEM software is also used for computing the current losses and iron losses.FEM simulations are carried out in the MATLAB-SIMULINK simulation. By coupling the FEM software to the MATLAB-SIMULINK simulation, more accuracy solution can be achieved.

In FEM analysis, differential equations are subjected to boundary conditions (essential and natural boundary conditions). Differential equations are completely solved in essential boundary conditions, but they cannot be solved in natural boundary conditions.

VI. Conclusion

This paper has introduced a research review on offline FEM sensorless control for BLDC-PM motor. Line to line PM flux linkage is used as a basis for the position estimation. The speed is obtained from rotor position and electromagnetic torque. The reliability of FEM is demonstrated through simulation and experimental results.

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