Summary on Sensorless permanent magnet Brushless DC Motor Control Strategies

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Abstract: This paper aims at discussing the development process and application of permanent magnet brushless DC motor. By referring to the related literatures, this thesis gives an overview of several common non-position sensor detection technologies, analyzing their strengths and weaknesses as well as a number of new and improved methods in practical applications. Besides, The application situation of the electric door with sensorless permanent magnet brushless DC motor was illustrated.

1 The introduction

The permanent magnet brushless DC motor (DC Motor Brushless, referred to asBLDCM) , is a multivariable and nonlinearcontrol object, integrated with modern electronic technology, controltheory and motor technology.Thefirst permanent magnet brushless DCmotor is manufactured in 1962, which marks the permanent magnet brushless DC motor to enter a new stage of development. Harrison and others , in the mid-1950s , for the first time ,to apply for a patent inapplication , which the motor`sbody tube commutationreplaces the mechanical commutation , thus the modern permanent magnet brushless DC motor prototype appeared. Germany's MANNESMANN company ,in 1978, launched the MAC permanent magnet brushless DC motor and its driving device, which makes permanent magnet brushless DC motor officially entered the practical stage of the mass production[1].

Permanent magnetic motor was widely used in vehicles, ships, industrial power, medical equipment and household electrical appliance etc, because of its characteristics of the little electromagnetic interference , the reliable operation, the convenient maintenance, economy and diversification etc.Traditional permanent magnetic motor are mostly based on the Holzer-position sensor, but the sensor accuracy and installation location greatly limits its dynamic performance and adjust the performance, as well , the cost of its production is too high. Therefore, with the no-position sensorbeginning to be used, many control methods of permanent magnet brushless DC motor rised .In this paper,the advantages and disadvantages of various methods and their improved technology will be summarized and discussed in detail.

2 The technology of Non-position

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Sensor Detection

2.1Based on the position of the back emf position detectiontechnology

(1)Based on the counter electromotive force passing zero detection

Based on the counter electromotive force passing zero detection is the simplest method. Its principle is prior to ignore the influence of armature reaction ; by disconnectedthe zero`s opposite electromotive force ,to measuresix key position signal, as shown in Figure 1. Literature [2,3] rotor through measure each phase permanent magnet brushless DC motor winding voltage, followed by the software calculated back EMF zero crossing, but they use the hardware detection circuit, and a phase compensation method differ. The calculation method of literature [4] is measuring the motor`s winding-line voltage, get zero position of the back EMF . It is function (1) of stator winding three-phase instantaneous voltage.

$$\begin{aligned} u_{as} &= r_s i_{as} + L_s \frac{di_{as}}{dt} + e_{as} \\ u_{bs} &= r_s i_{bs} + L_s \frac{di_{bs}}{dt} + e_{as} \\ u_{cs} &= r_s i_{cs} + L_s \frac{di_{cs}}{dt} + e_{cs} \end{aligned} \quad \text{----------(1)}$$

r_s ----------phase resistance

L_S ----------Phase Inductance

e_{as}, e_{bs}, e_{cs} ---Three-phase winding open-circuit voltage

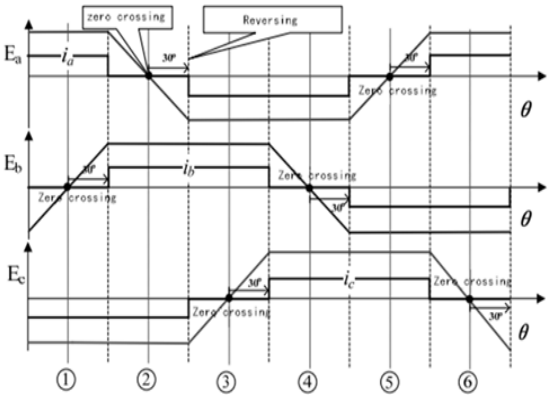


Fig.1Bemf zero and in phase diagram

Thistest technology is simple ,but some obvious shortcomings also exist. First of all, it is very difficult and vulnerable that measuring the zero position. The current solution is to use the depth filter circuit to filter.Second, when the motor's speed is slow ,the potential amplitude value of amplitude is too small, and difficult to get the accurate value. Third, in theory,trapezoidal wave is the sole criterion for judging back EMF waveform.Butin actual measurement it's difficult to get the trapezoidal wave .

To avoid the defects, A method of directly detecting back EDF ， without the assumed neutral point ， has been proposed, which could achieve full duty cycle operation .[5]At the same timethe method of direct detection zero ,with many limitations, has been proposed.in China.[6] In order to compensate the position error in real time, a new automatic correction test methodof rotor position phase , which using non conduction phase current deviation , is proposed [7].

(2)Fly-wheel diode method

Ogasawara et al ,in 1991 ,was first to proposethe method of continued flow diode, also known as the three-phase conduction method. The biggest advantage of the continuous flow diode detection method is to expand the speed range of the system ,in particular the low speed . But the method needs to open the loop for start ,withthe specific PWM modulation mode and six way detection circuit, which greatly increases the complexity of the hardware circuit. In addition,

in this method, six mutually isolated ways make the hardware design difficulty and cost too much. Therefore, at home and abroad, few people use this method, so the technology is not relatively mature and the relevant literature is relatively little.

(3)The electric potential integral method

Back EMF integral method is presented in literature [8], the basic idea of this method is: in the use of integral circuit to realize the detection of rotor magnetic pole position, with comparing resulting of the integrator output ad the reference voltage, in reversal signal. As shown in Figure 2 Schematic diagram shown in.

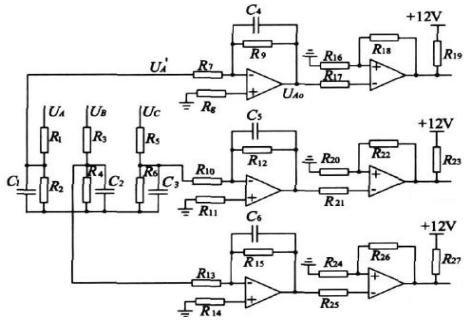


Fig.2 The principle diagram of the back emf integral method

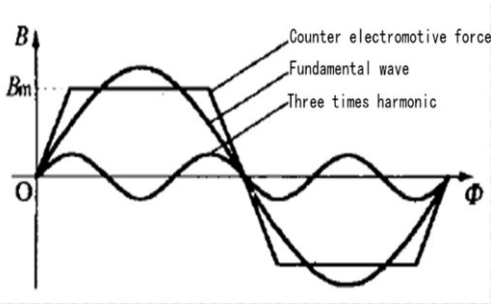
Inliterature [9],the method has used in the airconditioningcompressorapplication.

compared with the traditional back EMF method, back EMF integral method is relatively stable.

Another different principle of back EMF integral method: integral method of back EMF logic level,[10]]was carried out. The results indicate that only level detection in the detection of polar could greatly improve detection performance of the back EMF vibration amplitude at start and low speed.

(4) third harmonic detection method

Using Fourier series decomposition method to decompose the phase windings ofBLDCM.The integral value of third harmonic component and is the motor commutation point zero, as shown in figure



3.

Fig.3 Counter electromotive force, harmonic relationship

In literature[11] ,using TMS320F240 DSP chip to Proved the correctness of this method .Experimental results show the method is not affected by fly-wheel diode conduction effect, don't need a depth filter, and can detect the rotor position under high-speed operation.But in practical application, there are many obvious defects in assembly and low-speed operation. In order to improve the rotor position detection accuracy of the motor ,in high speed region, the method of the software phase locked loop of the literature[12] is achieved.

2.2 based on observer method

The main idea of the state observer method is to estimate the rotor position of the motor mathematical model by measuring the input of the actual system in real time.

In the literature [13], the motor control was carried out by using the extended Calman filter method, which was not affected by the back EMF waveformandthe change of system parameters, as well，the low speed performance was good.[14]Experimental results show it can completely replace the application of position sensor in fans, pumps and other occasions. Synovial observer to estimate thewaveform of the motor back EMF , in order to obtain commutation signals.[15] The results show that the observer combination can enhance the system disturbance and parameter changes of robustness. But this calculation method is very large, need to calculate the powerful DSP to solve, so its application is not very extensive.

2.3 Based on flux linkage function of rotor position detection

Due to the commutation time flux function value is very sensitive, so this method does not need the depth filter, and the flux function value and speed is independent, and low-speed range can extension. But the exact value of voltage and current ,and the accuracy of the parameters of the motor greatly reduces the robustness and anti-interference ability of the method. In order to make better correction of flux and position value, the control structure of double current loop is given in literature [16]. This method can be realized in full speed range.

2.4 based on the inductance of the position detection

(1) the current rate method

The main principle of current rate method is that calculate the slope of the detected current changes,next to get the position. In every electromotive force rate ,commutation positionis zero. This detection method need high-precision. In general, the sensor can obtain the value of the current signal. But ,the waveform with a small change is extremely difficult to detect,so few applications, in engineering ,were used.

(2) Method inductance

The inductance method has two forms: one is used in the salient pole permanent magnet brushless DC motor, the principle is to judge the change of the inductance of the motor winding during the starting process,with applying a specific detection voltage to the motor. However, this method is more difficult and can only be applied to the salient pole permanent magnet brushless DC motor, therefore, the present application is less. For strengthening the terminal voltage detection process more quick to get the position of the motor rotor, in literature [22], making a number of improvements, which using injection of weak high frequency AC signal in the stator windings. The other inductance method is using the method of applying the square wave voltage pulse to detect the current amplitude in the winding, through the inductance`s difference to get the rotor position signal, and the experimental results show better effect [17]. But the method also has a lot of disadvantages. It depends on the highly accurate current detection, and the ability to resist interference is poor. Ifdeliberately magnifying inductance characteristic of motor rotor, the detection will be more accurate. So it will become a very mature control method.

2.5 the artificial intelligence test

(1) fuzzy control

In the literature[18],at the frist Zadeh proposed the fuzzy control theory in 1960s. The fuzzy control method works realized by the fuzzy controller`s algorithm rules .

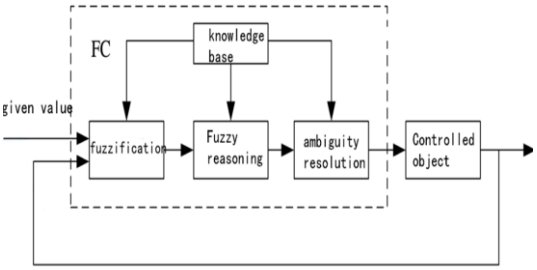


Fig.4 The fuzzy controller

Fuzzy control does not need to set up a dynamic analysis model of the object ;and if the design of fuzzy rules is proper, the whole system will have good robustness. In addition, the fuzzy controller has the advantages of simple design, good stability etc. In the literature[19] ,of this method,debugging time was limited, and operating environment is complex and changeable, but the complexity of the fuzzy rules beyond a certain limit. To solve these problems, using the genetic algorithm to make fuzzy control system to autonomous learning, freegroupandself-correction.

(2) neural network

The most common training method of neural network is BP (error propagation back) algorithm, which is proposed in 1986 by Rumelh, Hinton and Williams, as shown in figure 5.

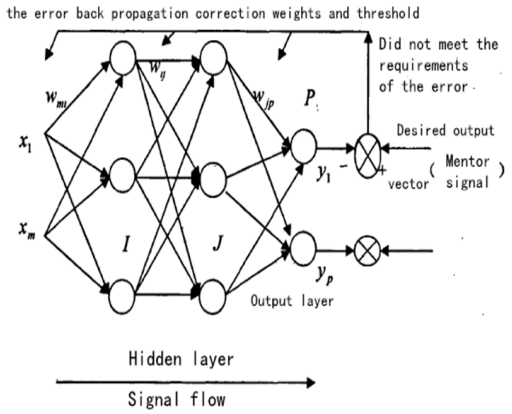


Fig. 5 BP network structure

BP neural network has simple algorithm structure and real-time control, but BP network also exist many shortcomings.If the system is so complex, the practicality will be not strong (the convergence speed is slow, and sometimes does not converge at global optimum). BP algorithm of reference [21] additional momentum and adaptive BP algorithm is used to improve these shortcomings.

(3) genetic algorithm

In 1969, the United States Michigan university professor Holland first proposed this method, later the DeJong, Goldberg and others summed up the formation of a new global optimization search algorithm [22]. Thegenes and the genetic algorithm is a bionic simulation of long-term evolution. In an iterative process, in each iteration must retain a set of candidate solution, according to the result and a number of indicators, then using genetic operator operation to obtain a new generation of candidate solutions, repeat the steps until the condition is met.

Genetic algorithm is efficient heuristic search without any auxiliary information help features, this is what the other traditional optimization method does not have.It is suitable for large-scale parallel computing.

3、in the application of electric door

The above principle of sensorless control methods and introduction ofheir advantages and disadvantages is a comprehensive, without specific application scenario.

For example ， the applicationdedicated to electric door motor, because electric door working environment is more special, some specific requirements will puts forward some specific requirements to use the working characteristic of motor.The traditional motor can't satisfy the requirements of the automatic door , in general electric motor is embodied in the following features:

(1)Electric door motor requires high controllability, and the good regulation widthand dynamic range.

(2)Electric door motor must possess simple structure, high reliability, good stability, strong adaptability .It should frequent start work at low speed under the bad environment, for a long time.

With the update of control technology, it is expected in the future of new control method will be more and more applied on the electric door ； these methods will also become the research hot spot in the future.

4、summary

This paper summarizes the basic principle, advantages, disadvantages and improving ways of several kinds of permanent magnet brushless dc motor sensorless control method 。

Sensorless motor control technology not only avoids weaknesses of the position sensor motor.but also makes full use of the software control technology.

With the development of the research,Artificial intelligence control method, wll be more applied to the electric door`s motor control category.

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