

# SPEED CONTROL OF SENSORLESS BLDC MOTOR WITH FIELD ORIENTED CONTROL

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**Abstract**— In a permanent magnet (PM) brushless dc motor (BLDC), the performance of Hall effect sensors are not reliable in some applications. The back electromotive force (back-EMF) signal is used instead since the zero-crossing points of back-EMF can be used to provide the rotor position information. In this paper, a new back-EMF difference detection method based on disturbance observer is proposed. The proposed structure can detect the back-EMF as well as back-EMF difference signal. The zero-crossing points of the back-EMF difference can be used directly for commutation, requiring no phase shift. Simulation and experiment results are provided to show the feasibility of the proposed method. *Index Term* Back electromotive force (EMF), brush less DC motor, disturbance observer, sensor less

**Keywords**—bldc motor,back emf estimation,sensorless,pi controller

## 1. INTRODUCTION

Brushless DC (BLDC) motors were extensively used in recent years due to its high efficiency and high reliability. In general, BLDC motors use Hall sensors to detect the corresponding position. However, in some extremely industrial applications, such as high temperature surrounding, small size, and economical limitation, it is not suitable to apply Hall sensors. For these reasons, many researchers pay attention to the drive schemes of sensor less BLDC motor. Many papers have presented several sensor less drives schemes for BLDC motors. These papers can be classified into three categories, i.e., direct back-EMF detection, indirect back-EMF detection and techniques based on estimation and models. Direct back-EMF detection method senses the back-EMF of the floating phase and its zero crossing points are used to trigger the commutation proposed a sensor less drive that detects back-EMF from line voltage difference.

Proposed another method based on terminal voltage difference. Unlike the conventional one, the method uses three additional comparing circuits to detect the back-EMF difference to eliminate phase delay. The other papers concern the issue that the motor speed range is narrow proposed. proposed a method that can extract third harmonic component from the stator phase voltage while the fundamental and other poly phase component are eliminated via a simple summation of three phase voltage proposed a sensor less drive based on conducting state of free-wheeling diodes connected in anti parallel with power transistors [5]. Some researchers also proposed techniques based on model-based estimation. apply sliding mode observer to estimate back-EMF, rotor position and speed.

filter to estimate speed and rotor position with the information of motor voltages and currents. The disturbance observer (DOB) structure which reduces

sensitivity to modeling error and enhances disturbance rejection properties is widely used in the field of motion control. The DOB is often applied to the inner-loop of the

motion control structure to reject equivalent disturbance as much as possible for achieving precise position tracking. It was first introduced. This paper presents a new model-based sensor less drive based on back-EMF difference detection method. Consider the back-EMF difference as input disturbance, the DOB structure can be applied on BLDC motor. In addition, the proposed structure can detect the back-EMF as well as back-EMF difference signal. The main advantage of this method is that the back-EMF difference does not require any phase shift from zero-crossing points; the algorithm is thus simpler and the performance is better. The organization of this paper is as follows. Section II describes the mathematical model of BLDC motors. Section III discussed the proposed sensor less drive. Section IV demonstrates the simulation results. Section V shows the due to the phase delay problem caused by filtering

## 2.MODEL OF BLDC MOTOR

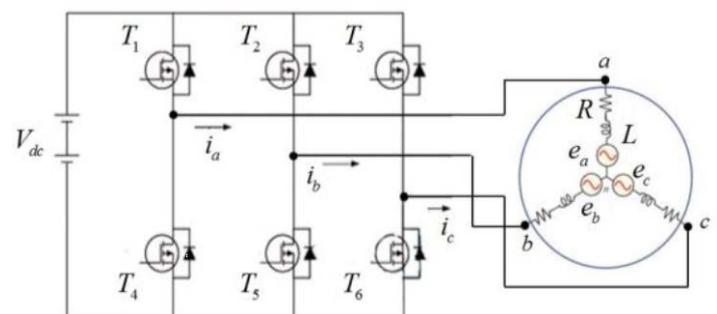


Fig.1.brushless dc motor

The BLDC motor model and the three phase inverter are The three IGBTs,  $T_1$ ,  $T_2$  and  $T_3$ , in the upper side of the inverter are called high side transistors in this paper; the other three IGBTs are called low transistors. Assuming that the stator resistances in the three windings are identical and the mutual inductances are constant, the phase voltage equation back-EMFs of each phase,  $R$  is the phase resistance, and  $L$  is the equivalent inductance in the stator windings. Fig. 2 illustrates the ideal relationship between back-EMF and current waveform. Only two phases will be conducted at the same interval,  $(0+60k)$  electrical degrees, where  $k = 0, 1, 2 \dots$ , and the third phase will be floating. The back-EMF waveform provides the information of the rotor position with zero-crossing points at  $(0+30k)$  electrical degrees. conventional sensor less drive, 30-degree phase shift from the zero-crossing points of the back-EMF signal can be utilized for commutation.

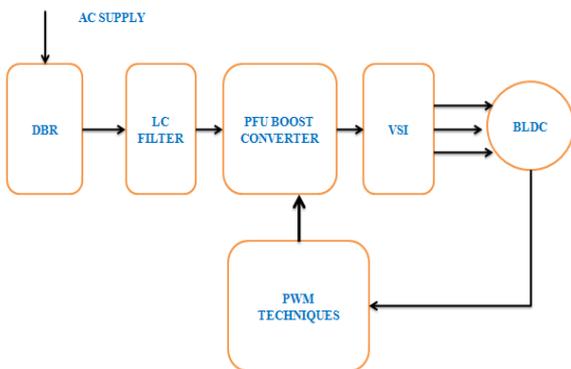


Fig.2.existing block diagram

#### 4.POSITION AND SPEED CONTROL USING SENSOR

PM motor drives require a rotor position sensor to properly perform phase commutation and/or current control. For PMAC motors, a constant supply of position information is necessary; thus a position sensor with high resolution, such as a shaft encoder or a resolver, is typically used. For BLDC motors, only the knowledge of six phase-commutation instants per electrical cycle is needed; therefore, low-cost Hall-effect sensors are usually used. Also, electromagnetic variable reluctance (VR) sensors or  $s$  have been extensively applied to measure motor position and speed. The reality is that angular motion sensors based on magnetic field sensing principles stand out because of their many inherent advantages and sensing benefits.

##### Position and Speed Sensors

As explained before, some of the most frequently used devices in position and speed applications are Hall-effect sensors, variable reluctance sensors and accelerometers. Each of these types of devices is discussed further below.

##### Hall-effect sensors

These kinds of devices are based on Hall-effect theory, which states that if an electric current- carrying conductor

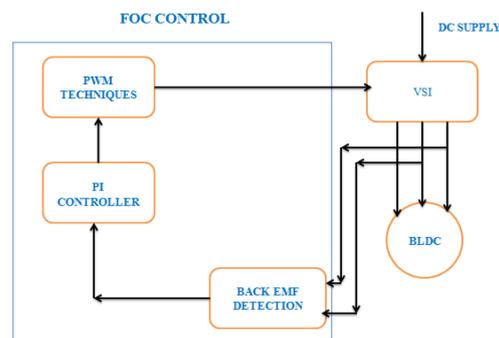
is kept in a magnetic field, the magnetic field exerts a transverse force on the moving charge carriers that tends to push them to one side of the conductor. A build-up of charge at the sides of the conductors will balance this magnetic influence producing a measurable voltage between the two sides of the conductor. The presence of this measurable transverse voltage is called the Hall-effect

#### 3.NEED OF SENSORLESS CONTROL

Position sensors can be completely eliminated, thus reducing further cost and size of motor assembly, in those applications in which only variable speed control (*i.e.*, no positioning) is required and system dynamics is not particularly demanding (*i.e.*, slowly or, at least, predictably varying load). In fact, some control methods, such as back-EMF and current sensing, provide, in most cases, enough information to estimate with sufficient precision the rotor position and, therefore, to operate the motor with synchronous phase currents. A PM brushless drive that does not require position sensors but only electrical measurements is called a sensor less drive.

The bldc motor provides an attractive candidate for sensorless operation because the nature of its excitation inherently offers a low-cost way to extract rotor position information from motor-terminal voltages. in the excitation of a three-phase bldc motor, except for the phase-commutation periods, only two of the three phase windings are conducting at a time and the no conducting phase carries the back-emf. there are many categories of sensor less control strategies [6]; however, the most popular category is based on back electromotive forces or back-emfs [17]. sensing back-emf of unused phase is the most cost efficient method to obtain the commutation sequence in star wound motors. since back-emf is zero at standstill and proportional to speed, the measured terminal voltage that has large signal-to-noise ratio cannot detect zero crossing at low speeds. that is the reason why in all back-emf-based sensorless methods the low-speed performance.

#### 5.PROPOSED SYSTEM



This paper proposed a new back-EMF detection method based on DOB. The estimated disturbance in the DOB structure is not used for compensation but used to detect the back-EMF difference. The following mathematical derivation illustrates how the DOB structure is applied on the BLDC motor. Three line voltage equations can be defined as

$$V_{bc} = V_{bn} - V_{cn} \quad (1)$$

$$V_{ab} = V_{an} - V_{bn} \quad (2)$$

$$V_{cn} = V_{cn} - V_{an} \quad (3)$$

From (1) and (2), the line voltage equation are

$$V_{ab} = Ri_{ab} + \frac{Ld(i_{ab})}{dt} + e_{ab}$$

$$V_{bc} = Rbc + \frac{Ld(i_{bc})}{dt} + e_{bc}$$

$$V_{ca} = Rca + \frac{Ld(i_{ca})}{dt} + e_{ca}$$

Line voltages are used to eliminate the influence of the neutral voltage part because the neutral voltage changes with the PWM switching signal, which makes conventional phase voltage and terminal voltage drive more complicated. Taking Laplace transform of (3) gives

$$V_{ab}(s) = Ri_{ab}(s) + LSi_{ab}(s) + e_{ab}(s)$$

$$V_{bc}(s) = Ri_{bc}(s) + LSi_{bc}(s) + e_{bc}(s)$$

$$V_{ca}(s) = Rica(s) + Lica(s) + e_{ca}(s)$$

Consider the line voltages as input, line currents as output and the back-EMF difference as the input disturbance, the block diagram of is obtained in where the

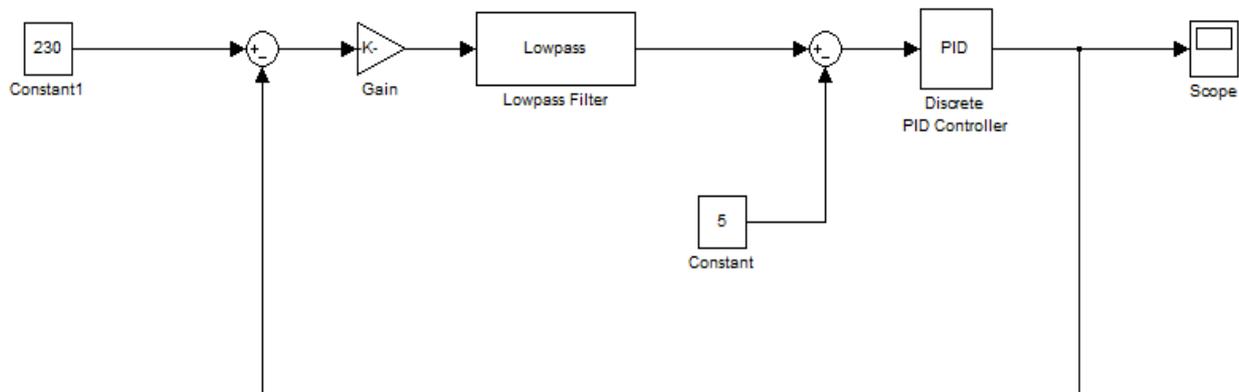


Fig.4.block diagram back emf estimation

### 6.SIMULATION OF THE PROPOSED SYSTEM

Simulations are presented to show the feasibility of the proposed method. Mat lab Simulink is used in this work. For simplicity, the initial rotor position is provided

voltage and current can be measured from sensors and the parameters of the plant, resistance and inductance, are provided from the datasheet. With this setup, the DOB structure can be applied on BLDC motor, as shown in Fig. 4, for estimating the back-EMF difference. The estimated back-EMF difference During any conducting interval, since only two phases are conducting and the third one is floating, the back-EMFs of the two conducting phases, the flat area in, are equal and opposite.

However, the back-EMFs are not used in this work because the zero-crossing points of back-EMF difference can be used directly for commutation. With two commutation points in each phase, the proposed back-EMF detection method provides the rotor position information with 60 degree resolution. Note that the 30-degree phase shift from zero-crossing points in conventional sensor less drive is not required. The disadvantage of conventional ones is that it should calculate time span for 30-degree phase shift from one complete electrical cycle. The need for 30-degree phase shift from zero-crossing points will increase the complexity of the algorithm and the inaccuracy of the commutation

The proposed sensor less drive will be demonstrated under H\_PWM\_L\_ON mode, as shown in Fig. 6, i.e. using PWM mode on the high side transistors and keeping constant turn-ON mode on the low side transistors. Forced alignment is used as starting procedure; once the rotor starts rotating, back-EMF differences are being detected by the DOB structure. Overall structure of the proposed sensor less drive. Phase voltage and current are measured from sensors and read through the analog-to digital converter .The DOB structure provides six commutation points to the three phase inverter.

in starting procedure since the starting technique is not discussed in this paper. After the rotor starts rotating, the commutation information is switched to the source of the proposed method. Fig. 8 shows the layout of the BLDC motor structure; it consists of a dc source, a three phase

inverter with six IGBTs and a permanent magnet synchronous machine. In this paper, the experiment prototype uses voltage divider and filter to measure phase voltages and shunt resistors to sense currents. The Q filter is designed in accord with the hardware implementation;

the cut off frequency is set to 2360 and the dc gain is set to 0.0081, as shown in Fig. 9. The relationship between the real back-EMF difference and the estimated back-EMF difference under 600 rpm and 1500rpm is shown in and As one can discover from the results, the estimated result lags the real signal

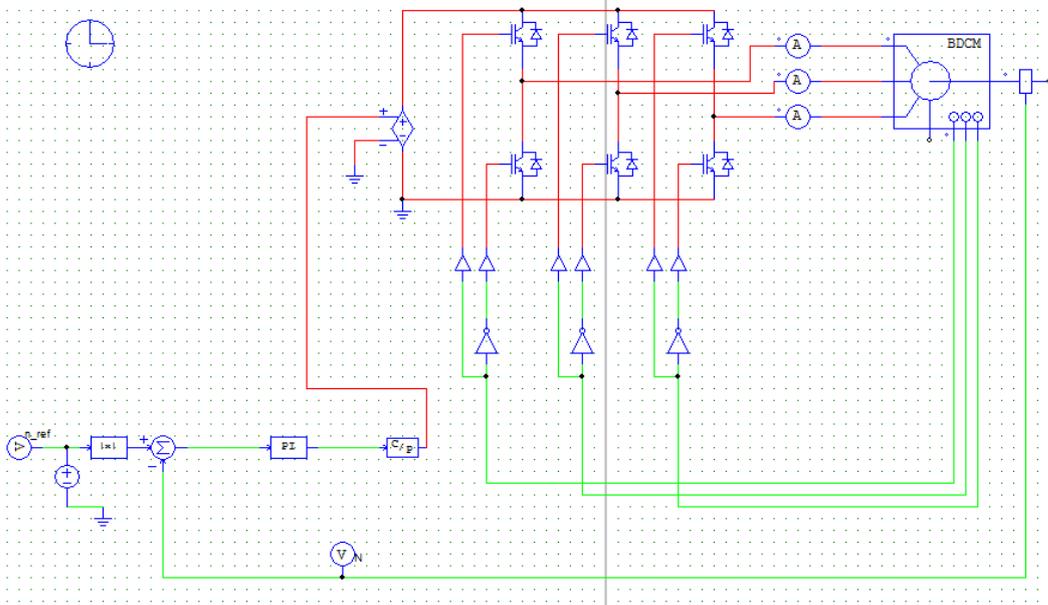


Fig.6.simulation of bldc motor

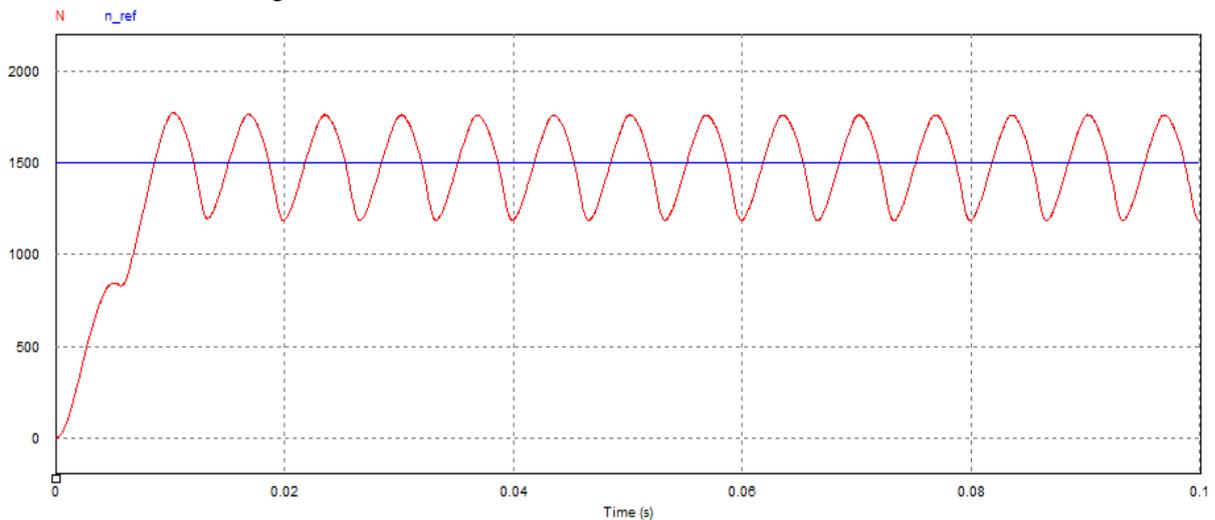


Fig.7.speed

EMF difference is used for commutation directly without any phase shift. The simulation and experiment results successfully match the theories in this paper

**7.CONCLUSION**

In this paper, a new back-EMF difference detection method is presented. The proposed method applies the back-emf structure on BLDC motors. The estimated back-

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