

Sensorless Control of BLDC Motor Using Back EMF Method

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ABSTRACT: Brushless dc motors and the modelled drives are working and moving faster in the market. BLDC drives are patterned with six-step commutation with commutation controlled using position sensors. Sensorless drives are preferred to minimize complexity and cost of the system. Here, direct detection of back EMF, is presented for sensorless BLDC drives. For this method, no need of measuring motor neutral voltage in order to measure the back EMF. The off period of PWM detects the floating motor windings true back emf. Because, motor terminal voltage is proportional directly to phase of back EMF in this interval. This theory presents the back EMF control method.

I. INTRODUCTION

Brushless DC Motor works with electronic commutation method to supplement the electro-brush in DC drives. It reduces the disadvantages of DC motor, like brushed commutation. Because of the advantages of brushless drives such as wide range of speed, good mechanical linearity characteristic, long life service, easy maintain, high and good reliability, less noise, no spark during commutation etc, this drives are extensively used in household and electrical appliances, automotive industrial equipment, and military equipment is applied in different field on the brushless DC drives control. Presently, brushless DC drive development is moving intelligent, digital, position sensors and direction control.

II. PRINCIPLE OF BRUSHLESS DC MOTOR

Brushless DC motor by motor ontology, location, signal detecting device and electronic reversing switch circuit (inverter) consists of three parts. It's principle structure as shown in Figure 1.

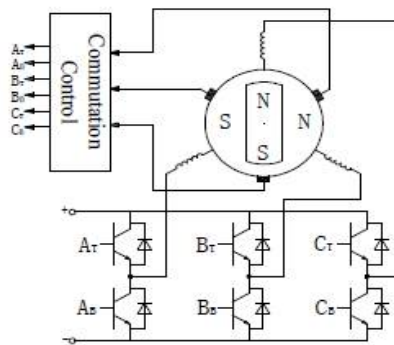


Fig 1: Principle diagram of brushless DC motor

The stator (armature) winding power, position signal real time detection of rotor position detection device signals, electronic commutation switch control circuit changed armature winding on / off, thus changing the stator magnetic

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field direction, ensure appropriate torque angle, driven rotor spinning. Stator flux of movement is stepping and changes its frequency depending on the motor speed.

III. BACK - EMF METHOD

Rotor position detection of signals is a Brushless DC motor without position sensor control and key. In recent years, both at home and abroad where there have been many signal detection method. " Back - EMF method " is by far the most mature, the most effective and the most widely used method of rotor position detection. It also includes three main methods : zero - crossing method, phase - lock loop method and integration method. Back electromotive force method usually refers to the zero - crossing method.

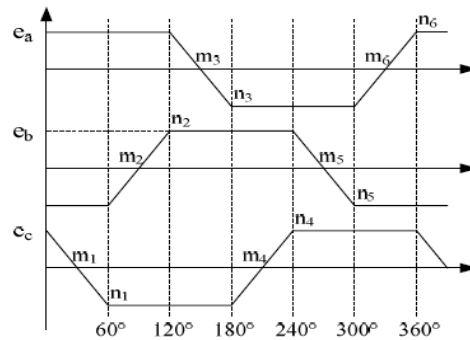


Fig 2: Back EMF waveform

"Double on three-phase six-State" square wave brushless DC motors of operation modes, requires every 60 ° angle control for stator winding current commutation. At any moment of inverter power supply, there is always a phase of its upper and lower leg is in a disconnected state, detects the - phase winding the back electromotive force of zero-crossing points, you can speculate are six key rotor position signals. As shown in Figure 2, are zero-cross point M1~M6 further delay (30 ° +k*60 °) angle commutation point is. According to the phase corresponding to the point of changing the rotor position, according to table 1, conduction and switching the transistor, you can drive motor functioning.

Tab. 1 Relationship of back EMF zero-crossing and rotor position

Motor rotor position signals						Rotor position
zero-cross point	Delay angle	Comm-utation point	Ea	Eb	Ec	
m1	30°	n1	+	-	+ → -	0°~60°
m2	30°	n2	+	- → +	-	60°~120°
m3	30°	n3	+ → -	+	-	120°~180°
m4	30°	n4	-	+	- → +	180°~240°
m5	30°	n5	-	+ → -	+	240°~300°
m6	30°	n6	- → +	-	+	300°~360°

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IV. SPACE VECTOR PULSE WIDTH MODULATED CONTROL

Space vector pulse width modulating strategy is an innovative method which provides an efficient feature. Hence, this method is chosen as best of all PWM methods for the application of variable supply frequency drives. It has excellent performance characteristics; hence extends the applications in inverter drives with reduced harmonics[4].

V. MERITS OF SPACE VECTOR METHOD

- It provides good fundamental inverter voltage.
- Spectrum of harmonics is improved.
- It is easy to implement in digital controllers like microcontrollers and DSPIC processors.

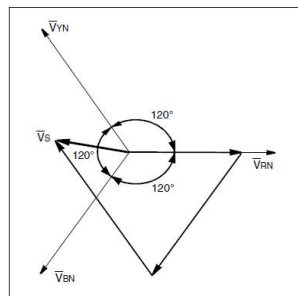


Fig 3: Resultant space vector and 3φ voltage

The sum of 3 vectors is 0 for balance supply system. So, it is represented as single reference space vector(\vec{V}_s). The voltage and frequency of a motor is controlled by controlling frequency and amplitude of \vec{V}_s . Space vector modulation controlled voltage source inverter is shown in the below figure 4.

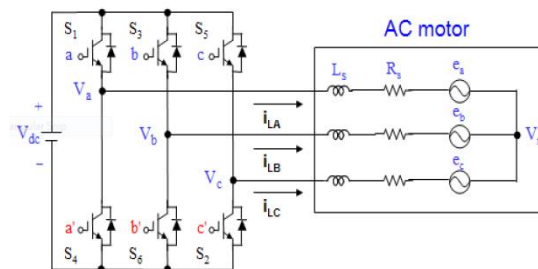


Fig 4: VSI for AC motor

To operate the inverter drive in safe mode, in each leg only one switch should conduct at a time. When Q1 is in conduction Q2 must be in reverse bias condition and vice versa. In SVPWM method 8 states of switching is provided.

The table below shows switching instance:

Switching State	On Switches	V _{RN}	V _{YN}	V _{BN}	Space Voltage Vector
0	Q0, Q2, Q4	0	0	0	\vec{V}_0
1	Q1, Q2, Q4	2/3 V _{dc}	-1/3 V _{dc}	-1/3 V _{dc}	\vec{V}_1
2	Q1, Q3, Q4	1/3 V _{dc}	1/3 V _{dc}	-2/3 V _{dc}	\vec{V}_2
3	Q0, Q3, Q4	-1/3 V _{dc}	2/3 V _{dc}	-1/3 V _{dc}	\vec{V}_3
4	Q0, Q3, Q5	-2/3 V _{dc}	1/3 V _{dc}	1/3 V _{dc}	\vec{V}_4
5	Q0, Q2, Q5	-1/3 V _{dc}	-1/3 V _{dc}	2/3 V _{dc}	\vec{V}_5
6	Q1, Q2, Q5	1/3 V _{dc}	-2/3 V _{dc}	1/3 V _{dc}	\vec{V}_6
7	Q1, Q3, Q5	0	0	0	\vec{V}_7

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The switching patterns from 1-6 are active states, where motor gets energized from the supply. Remaining two states are inactive states as energy is not supplied. The below figure shows representation of switching in space vector[5].

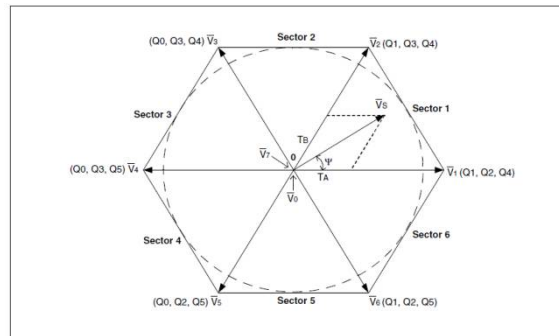


Fig 5:Vector Space hexagon

In this figure the hexagon is split to 6 sectors of 60° . Two active vectors bounds each sector. Two inactive states are vectors with amplitude zero and starts in the origin of hexagon. Since this method has high amplitude of line-line voltage, motor generates high torque and improves the dynamic response[6]. Due to the sequential switching of inverter, the resultant is \vec{V}^* . The switching frequency of inverter circuit is high enough to avoid the audible noise during switching.

Switching states and corresponding outputs of space vector method:

Voltage Vectors	Switching Vectors			Line to neutral voltage			Line to line voltage		
	a	b	c	V_{an}	V_{bn}	V_{cn}	V_{ab}	V_{bc}	V_{ca}
V_0	0	0	0	0	0	0	0	0	0
V_1	1	0	0	$2/3$	$-1/3$	$-1/3$	1	0	-1
V_2	1	1	0	$1/3$	$1/3$	$-2/3$	0	1	-1
V_3	0	1	0	$-1/3$	$2/3$	$-1/3$	-1	1	0
V_4	0	1	1	$-2/3$	$1/3$	$1/3$	-1	0	1
V_5	0	0	1	$-1/3$	$-1/3$	$2/3$	0	-1	1
V_6	1	0	1	$1/3$	$-2/3$	$1/3$	1	-1	0
V_7	1	1	1	0	0	0	0	0	0

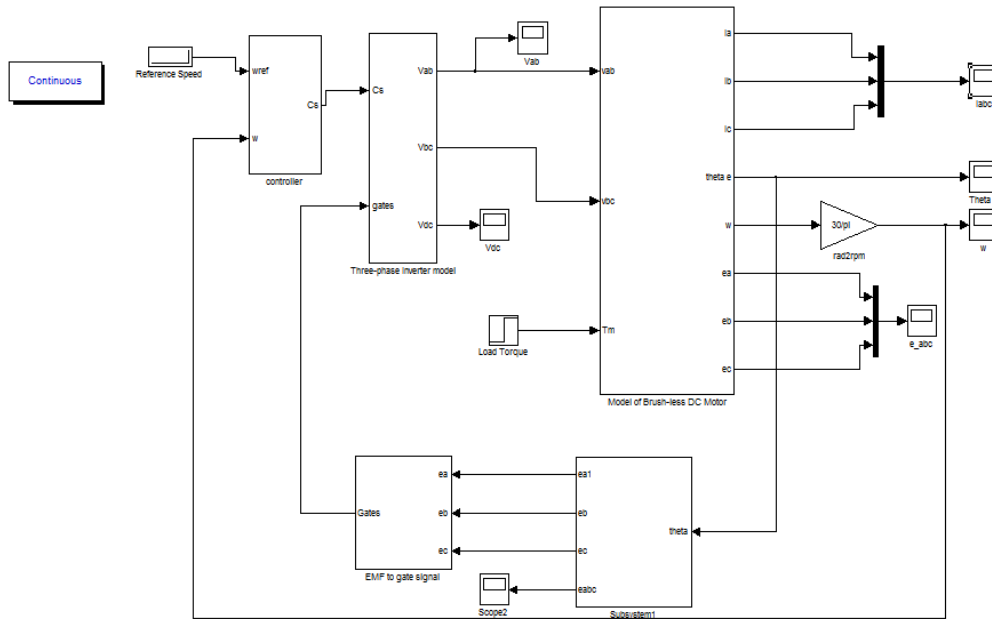
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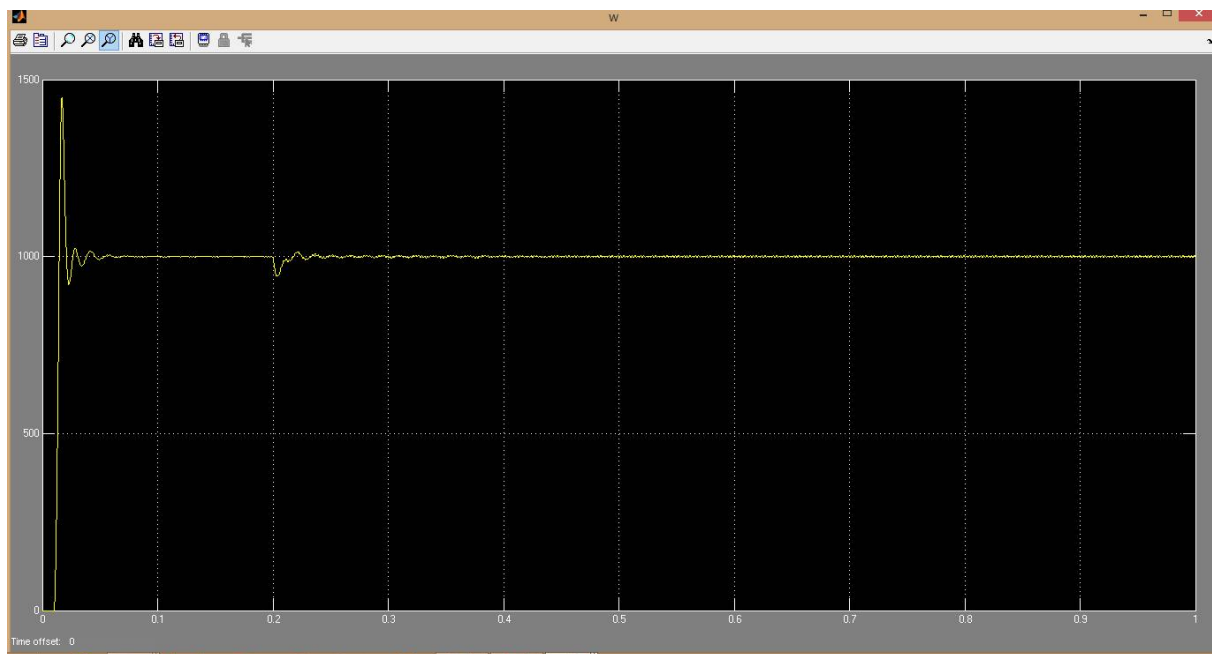
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VI. SIMULATIONS AND RESULTS

The simulation of sensorless control of BLDC motor is shown below,



Simulation of sensorless control of BLDC motor

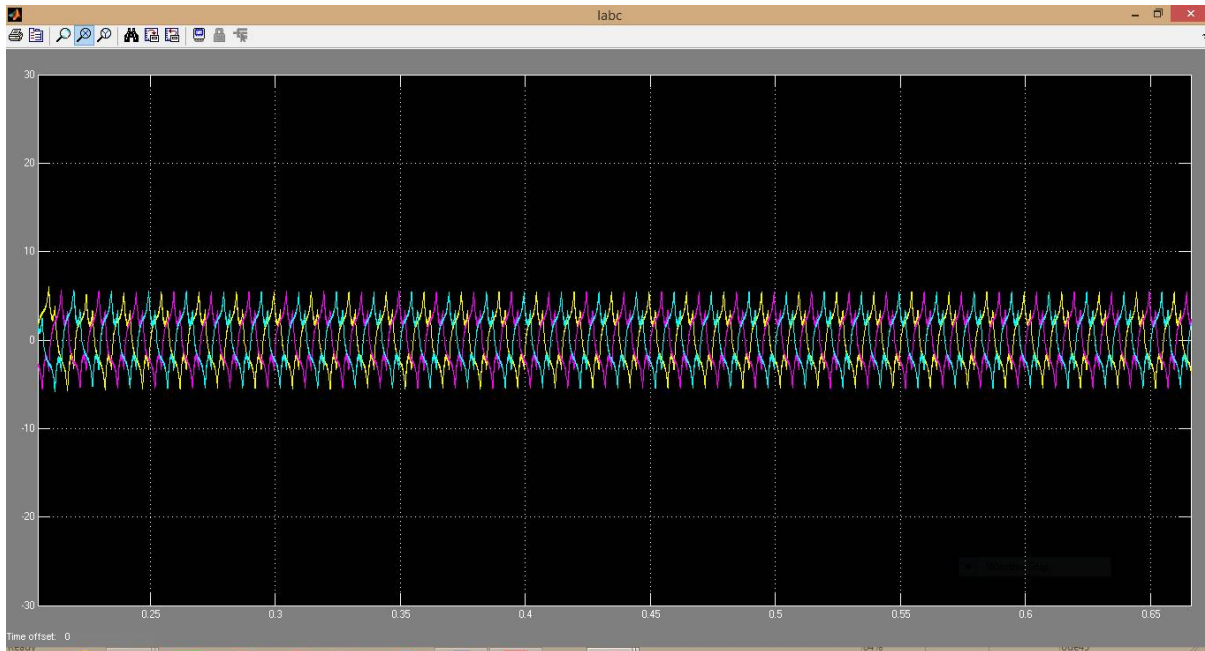


Speed of BLDC motor

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Back emf current

VII. CONCLUSION

Experimental results show that detection of back electromotive force projections of zero - crossing points and thus the rotor position is accurate and reliable, to correct commutation of brushless DC motor operation. Sensorless control of this technology is practical and effective, study on Sensorless control system is of important practical significance and broad development prospects.

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