ADVANCED ROTOR POSITION DETECTION TECHNIQUE FOR SENSORLESS BLDC MOTOR CONTROL

S.Joshuwa, E.Sathishkumar, S.Ramsankar

***Abstract* — Brushless DC Motor drives have made a successful entrance into various sectors of industry such as aerospace, automotive and home appliances due to its simple structure. The accurate knowledge of the rotor position is required for good performance of brushless DC motors the need for the rotor angle information in BLDC has been satisfied by use of some form of rotor position sensor. The position sensor used in BLDC drives have the disadvantages of additional cost, electrical connections, mechanical alignment problems, and disadvantage of being inherent source of unreliability. These bottlenecks results in several sensor less technique in recent years. A proposed sensor less scheme is used to overcome the disadvantages of sensored scheme. The rotor position detection can be estimated even at standstill and running conditions. The methods which is proposed in this project is 1. Back EMF ZCD 2. RF Injection method.**

***Index Terms*— Brushless DC Motor, Back EMF ZCD**

I. INTRODUCTION

During the last two decades, a lot of research on sensor less control technique for BLDC motor has been conducted. The paper [1] describes the analysis, design, and implementation of a high performance and cost effective sensor less scheme for BLDC Motors. It has some advantages such as Elimination of motor neutral voltage, Elimination of fixed phase shift circuit, Low starting speed, Cost effective. The voltage spikes are created by the residual current when the armature current is blocked by power switches, this is the disadvantage. The paper [2] describes about the commutation tuning and speeding up of square wave winding current tracking response for sensor less BLDC motor.

Low cost position sensor less control scheme [3] for BLDC motor is described. Rotor position information is determined by indirectly sensing the back emf from one of the three motor terminal voltages of three phase motor. The two typical control methods [4] for BLDCM is square wave control method and the other is sinusoidal current control method.

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The accuracy for the position information is different between two control methods. The paper [5] is used to reduce commutation torque ripple in position sensor less BLDC motor drive. The proposed technique is the 'Back EMF ZCD' is used to determine the 'Advanced Rotor Position Detection Technique for Sensor less BLDC Motor control. Back EMF is obtained from the supply, with the voltage divider connected with low pass filters and comparator circuit. When this Back EMF is send to zero crossing detector circuit a positional pulse used for rotor position detection is obtained. The Positional Pulse is compared with the hall pulse and their phase difference is obtained. When the motor is in standstill conditions the back EMF will be zero, so rotor Position cannot be determined. To determine the rotor position at both in standstill and running conditions back EMF ZCD method is used.

II. SENSORLESS CONTROL OF BLDC MOTOR

Brushless dc (BLDC) motors, with their trapezoidal electromotive force (EMF) profile, requires six discrete rotor position information for the inverter operation. These are typically generated by Hall- effect switch sensors placed within the motor. However, it is a well-known fact that these sensors have a number of drawbacks. They increase the cost of the motor and need special mechanical arrangements to be mounted. Further, Hall sensors are temperature sensitive, and hence limit the operation of the motor. They could reduce system reliability because of the extra components and wiring. so sensor less method is the reliable method used in harsh environments.

There are three independent methods for determining the Hall configuration. The selection of which method to use will depend on the information provided.

1. Hall Based Commutation Sequence Provided.
2. Back EMF Waveforms.

Hall Based Commutation Sequence Provided:

Hall Based Commutation Sequence Provided This method is the straight forward and requires the least amount of effort on the part of the user. This information is usually provided in the form of a diagram or table and may have different titles such as "Block Commutation" or "Brushless DC Motor Timing Diagram". Some of these diagrams represent motor phase voltage during trapezoidal (six-step) commutation. Other tables may represent the state of the high-side and low-side MOSFETs of the half-bridge amplifiers for all three phases during trapezoidal commutation. Either method conveys adequate information about driving the motor phases based on Hall Effect sensor states. The relationship between the Hall Effect sensors themselves is always consistent. In other words the Hall Effect sensor sequence seen in can be found in all motors with 120-degree Hall Effect sensors when the motor rotates. However, the direction of rotation, CW or CCW, necessary to produce this relationship can vary across different motors. Very often the binary state of the three Hall Effect sensors will be combined to create a 3-bit binary word. The mapping between the Hall states and the three-bit word. Below the binary word representation in is tables that represent the states of the MOSFETs of the half-bridges.

Every Hall state has a unique half-bridge state defined as follows:

A+ = Phase A high side MOSFET closed

A- = Phase A low side MOSFET closed

B-= Phase B high side MOSFET closed

C-= Phase B low side MOSFET closed

C+ = Phase C high side MOSFET closed

D- = Phase C low side MOSFET closed

If the state of a MOSFET for a particular Hall state is not defined then it is assumed to be 0pen. For example during Hall state 1-0-1, MOSFETs A-, B+, C+ and C- are all open. Below the table of MOSFET states in is a diagram of the relative voltages through each motor phase based on the Hall states (and subsequent MOSFET states). For instance in Hall state 1- 0-1, the path of the current begins at the voltage source, flows through the high side MOSFET of phase A, through motor winding A, through motor winding B, through the low side MOSFET of phase B, and finally to the ground plane. BACK EMF:

When a BLDC motor rotates, each winding generates a voltage known as back electromotive Force or back EMF, which opposes the main voltage supplied to the windings according to Lenz's Law. The polarity of this back EMF is in opposite direction of the energized voltage.

Back EMF depends mainly on three factors:

- Angular velocity of the rotor
- Magnetic field generated by rotor magnets
- The number of turns in the stator windings.

Once the motor is designed, the rotor magnetic field and the number of turns in the stator windings remain constant. The only factor that governs back EMF is the angular velocity or speed of the rotor and as the speed increases, back EMF also increases. The motor technical specification gives a parameter called, back EMF constant that can be used to estimate back EMF for a given speed. The potential difference across a winding can be calculated by subtracting the back EMF value from the supply voltage. The motors are designed with a back EMF constant in such a way that when the motor is running at the rated speed, the potential difference between the back EMF and the supply voltage will be sufficient for the motor to draw the rated current and deliver the rated torque. If the motor is driven beyond the rated speed, back EMF may increase substantially, thus decreasing the potential difference across the winding, reducing the current drawn which results in a drooping torque curve. The last point on the speed curve would be when the supply voltage is equal to the sum of the back EMF and the losses in the motor, where the current and torque are equal to zero.

The conventional back emf technique of three phase BLDC motor is driven with 120 deg six-step conducting diode. At one time instant, only two out of three phases are conducting current. For example, when phase A and phase B conduct current, phase C is floating. This conducting interval lasts 60 electrical degrees, which is called one step. A transition from one step to another Sensor less Control of BLDC Motor. Different step is called commutation. So totally, there are 6 steps in one cycle. The first step is AB, then to AC, to BC, to BA, to CA, to CB and then just repeats this pattern. Usually, the current is commutated in such way that the current is in phase with the phase back EMF to get the optimal control and maximum torque/ampere. The commutation time is determined by the rotor position. Since the shape of back EMF indicates the rotor position, it is possible to determine the commutation timing if the back EMF is known. The phase current is in phase with the phase back EMF. If the zero crossing of the phase back EMF can be measured, we will know when to commutate the current. As mentioned before, at one time instant, since only two phases are conducting current, the third winding is open. This opens a window to detect the back EMF in the floating winding. The terminal voltage of the floating winding is measured. This scheme needs the motor neutral point voltage to get the zero crossing of the back EMF, since the back EMF voltage is referred to the motor neutral point. The terminal voltage is compared to the neutral point, then the zero crossing of the back EMF can be obtained. In most cases, the motor neutral point is not available.

In practice, the most commonly used method is to build a virtual neutral point that will, in theory, be at the same potential as the centre of a Y wound motor and then to sense the difference between the virtual neutral and the voltage at the floating terminal. The virtual neutral point is built by resistors. This scheme is quite simple. It has been used for a long time since the invention. Because of the PWM drive, the neutral point is not a standstill point. The potential of this point is jumping up and down. It generates very high common mode voltage and high frequency noise. So we need voltage dividers and low pass filters to reduce the common mode voltage and smooth the high frequency noise, . For instance, if the dc bus voltage is 300 V, the potential of the neutral point can vary from zero to 300 V. The allowable common mode voltage for a comparator is typically a few volts, i.e. 5 V. We will know how much attenuation should be. Obviously, the voltage divider will reduce the signal sensitivity at low speed, especially at start-up where it is needed most .On the other hand, the required low pass filter will induce a fixed delay independent of rotor speed. As the rotor speed increases, the percentage contribution of the delay to the overall period increases. This delay will disturb current alignment with the back EMF and will cause severe problems for commutation at high speed. Consequently, this method tends to have a narrow speed range. In the past, there have been several integrated circuits, which enabled the sensor less operation of the BLDC. A few other schemes for sensor less BLDC motor control were also reported in the literature. The back EMF integration approach has the advantage of reduced switching noise sensitivity and automatically adjustment of the inverter switching instants to changes in the rotor speed. The back EMF integration still has accuracy problems at low speeds the rotor position can be determined based on the stator third harmonic voltage component. The main disadvantage is the relatively low value of the third harmonic voltage at low speed. In, the rotor position information is determined based on the conducting state of free-wheeling diodes in the unexcited phase. The sensing circuit is relatively complicated and low speed operation is still a problem

The proposed back emf detection method describes that, instead of detecting the zero-crossing point (ZCP) of the non-excited motor back electromagnetic force (EMF) or the average motor terminal to neutral voltage, the true zero-crossing points of back EMF are extracted directly from the supply with simple RC circuits and comparators. In contrast to conventional methods, the neutral voltage is not needed and the diode freewheeling currents in the non-conducted phase are eliminated completely; therefore, the commutation signals are more accurate and insensitive to the common-mode noise. As a result, the proposed method makes it possible to achieve good motor performance over a wide speed range and to simplify the starting procedure. The detailed circuit model is analysed and some experimental results are obtained.

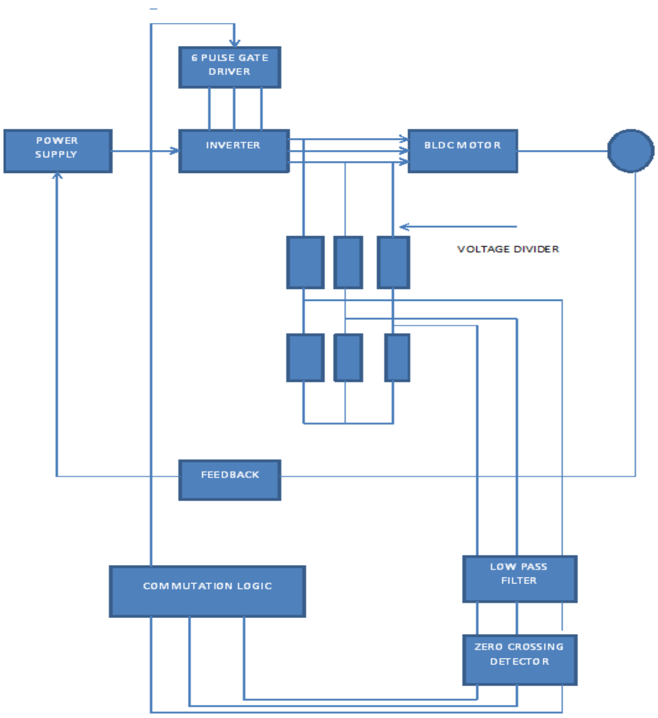

Fig1. Overall Block Diagram

A power supply is given to the inverter. The three phase output of the inverter is applied to the motors stator windings. From the supply, voltage divider is connected, with the RC low pass filter and a zero crossing detector circuit to produce the back EMF for three phases. Low pass filter is a filter that passes low frequency signals but attenuates higher frequency signals. The actual amount of attenuation for each frequency varies from filter to filter. The low pass filter has been designed for a frequency of 300 Hz.

A zero crossing detector literally detects the transition of a signal waveform from positive and negative, ideally providing a narrow pulse that coincides exactly with the zero voltage condition. The Back EMF signals are send to the zero crossing detector the positional pulse are produced. A voltage divider (also known as a potential divider) is a simple linear circuit that produces an output voltage (Out) that is a fraction of its input voltage (*V*in). Voltage division refers to the partitioning of a voltage among the components of the divider. To drive the BLDC motor, an electronic commutation circuit is required. The widely used commutation methods for the BLDC motor are trapezoidal (or six-step), sinusoidal, and field oriented control (FOC) (or vector control). The sinusoidal drive scheme replaces the flat peak of the trapezoid with a sinusoidal waveform that matches more closely the back-EMF. It is necessary to overlap the commutation of phases, selectively firing more than one pair of power switching devices at a time.

III. SIMULATION RESULTS

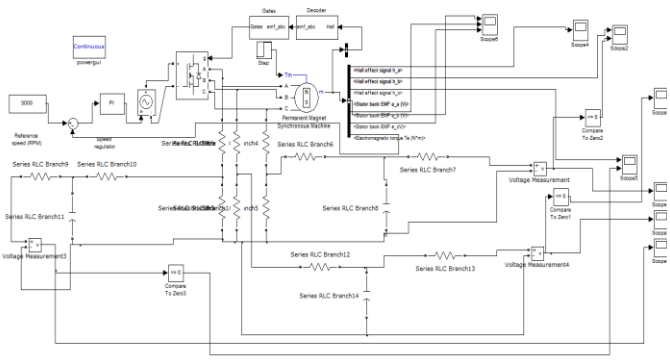

Fig2. Overall Simulation Diagram

A three BLDC motor is fed to the to the inverter bridge and it is connected to controlled voltage source The inverter gates signals are produced by decoding hall effect signals. The three phase output of the inverter is applied to the motors stator windings. From the supply voltage divider is connected, with the RC low pass filter and a compare to zero circuit to produce the back emf for three phases.

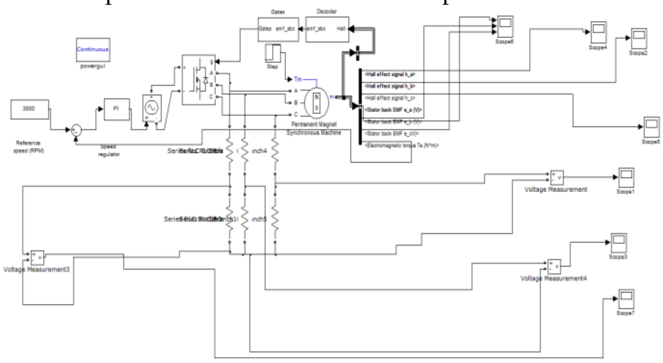

Fig3. Without Filter

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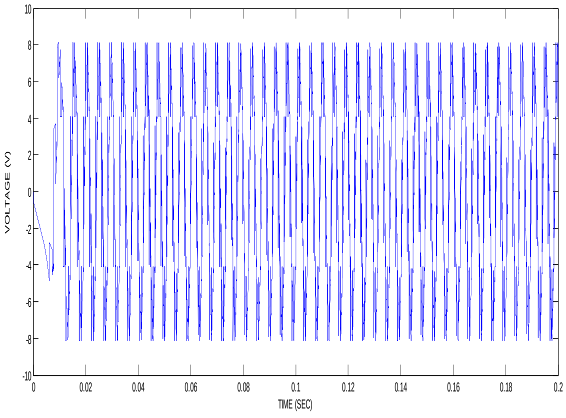

Fig3.1(a) Back Emf for Phase A $_{e\_a}$

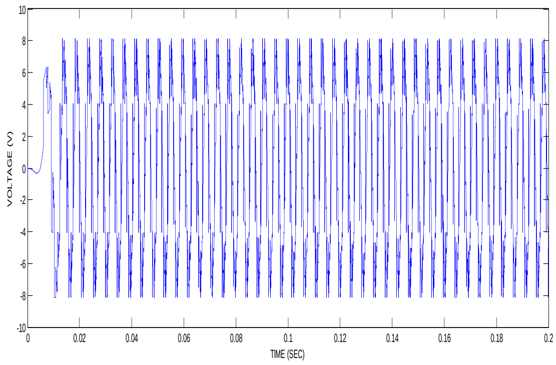

Fig3.1(b) Back Emf for Phase B $_{e\_b}$

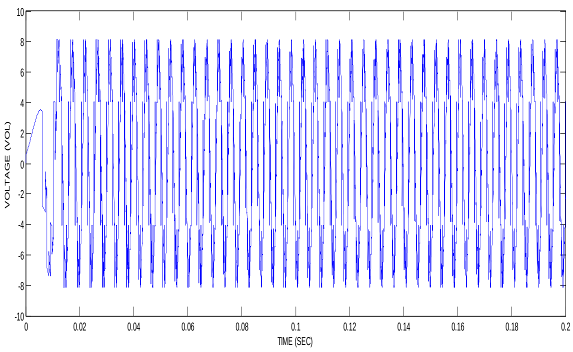

Fig3.1(c) Back Emf for Phase C$_{e_c}$

As all these waveform contains spikes, the circuit with a RC low pass filters is designed. The circuit diagram with RC low pass filter is shown below.

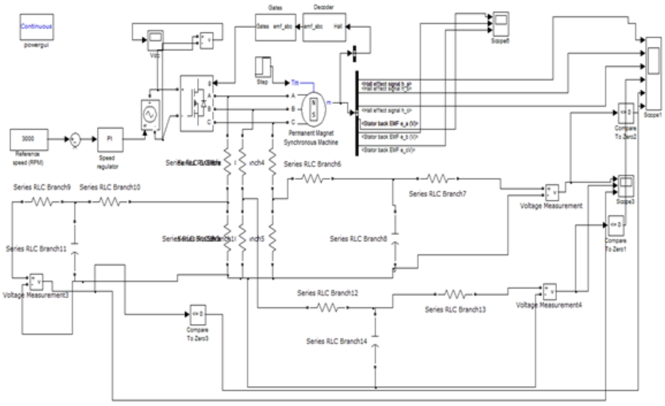

Fig3.2 With RC Filter

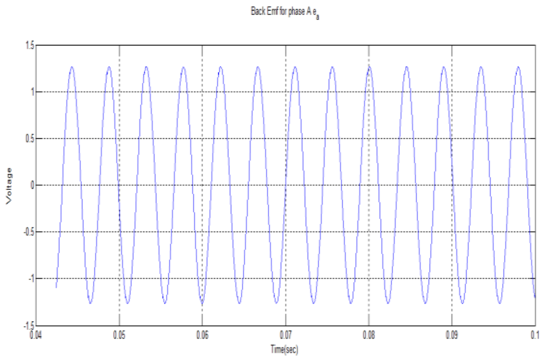

Fig3.2(a) Back Emf for phase A

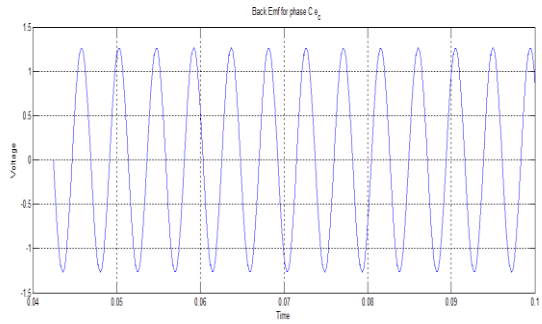

Fig3.2(b) Back Emf for Phase B

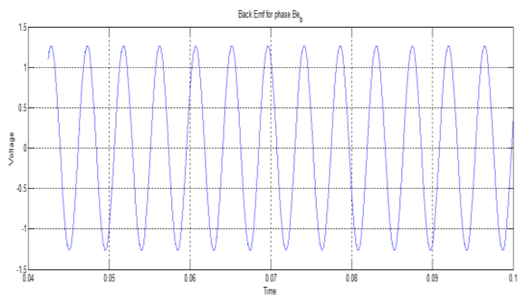

Fig3.2(c) Back Emf for Phase C

IV. RF INJECTION METHOD

High frequency injection method is used to detect the rotor position. The high frequency inductance (Lss) caused by structural and magnetic saturation saliency of motor modulates the high frequency impedance of each phase and creates resultant high frequency current distribution into the phases. The high frequency current pattern can be modeled successfully and used according to deduce rotor position.

V. CONCLUSION AND FUTURE TRENDS

A simple technique to detect back EMF using RC filter and comparator is defined. This method provides an amplified version of the back EMF. Detection of Rotor Position is determined using Back EMF ZCD. Simulation and experimental results are shown which validate the suitability of the proposed method. Simulation of the proposed method is done by using MATLAB/SIMULINK. New machine design also is an alternate solution to sensor less operation. Some research is going on to add the special sensing winding to the machine to indicate the rotor position. The design of BLDC motor is not standardized yet. Optimized design of the BLDC motor that achieves higher efficiency with lower cost is desirable. dynamic response and stability analysis of the sensor less control, optimal current controller gain selection.

VI. ACKNOWLEDGEMENT

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