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A BACK EMF DETECTION METHOD IS IMPLEMENTED FOR SENSORLESS BLDC MOTOR

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*Abstract***—** ***In recent years BLDC Motor and their drives are becoming a major market trend in home appliances, automotive applications and in HVAC industry for their better reliability, silent operation and high efficiency with low maintenance. For a traditional BLDC Motor, a six step commutated pattern with position sensors are provided which increases the cost of the BLDC Motor. Hence the preference is switch over to the sensorless drive to reduce the cost and complexity. The existing conventional sensorless scheme which has its own limit for the applications which is the major drawback of back emf sensing based on motor neutral voltage. In this paper a new technique is implemented with direct back emf detection for sensorless BLDC Motor drives. To measure the back emf, there is no need of motor neutral voltage. During the Off time of the PWM, the terminal voltage of the motor is directly proportional to the phase back emf. For the back emf sensing, there is no need of attenuation filtering. At low cost, the wider motor speed range had achieved with superior performance which shows with the help of MATLAB/ SIMULINK Software.***

Keywords— ***BLDC Motor, Zero Cross Detector, Sensor less Torque Ripple.***

I. INTRODUCTION

Brushed DC motors depend on a mechanical system to transfer current, while AC and brushless DC motors use an electronic mechanism to control current. The brushed motors have a wound armature attached to the center with a permanent magnet bonded to a steel ring surrounding the rotor. As the brushes come into contact with the commutator the current passes through to the armature coils. Brushed motors are not only larger than their brushless counter parts; they also have a shorter service life.

The brushes in the brushed motor are usually made of carbon or graphite compounds which wear during use. These brushes will require maintenance and replacement over time, so the motor will need to be accessible to ensure continued service. As the brushes wear the not create dust but noise caused by the rubbing against the commutators.

AC induction motors and BLDC motors do not depend upon the mechanical system (brushes) to control current. The AC and BLDC motors pass current through the stator (electromagnet) which is connected to AC power directly or via a solid-state circuit. In AC induction motors the rotor turns in response to the "induction" of a rotating magnetic field within the stator, as the current passes.

Rather than inducing the rotor in a brushless DC motor, permanent magnets are bonded directly to the rotor, as the current passes through the stator, the poles on the rotor rotate in relation to the electromagnetic poles created within the stator, creating motion. A BLDC motor is highly reliable since it does not have any brushes to wear out and replace.

Advances in the semiconductor and magnetic material industries made it possible to mass-produce low cost BLDC machines in large quantities. Ideally, these motors can be deployed in any of the areas where more traditional (brushed dc, synchronous, and induction) motors have been used. The BLDC motors are particularly gaining market share in robotics, consumer appliances, power tools, and manufacturing automation. A typical BLDC motor consists of a Permanent Magnet Synchronous machine (PMSM) fed with a Voltage Source Inverter (VSI).

As the rotor magnets typically have high electrical resistance, the rotor losses are small contributing the higher efficiency. The motor case can be entirely enclosed and protected from dirt or other foreign matter. A BLDC motor, for the same mechanical work output, will usually be smaller than a brushed DC motor, and always smaller than an AC induction motor. The BLDC motor is smaller because its body has less heat to dissipate. From that standpoint, BLDC motors use fewer raw materials to build, and are better for the environment. Brushless motors have longer service lives and are cleaner and quieter because they do not have parts the rub or wear during use.

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II. SENSORLESS METHOD WITH BACKEMF DIFFERENCE ESTIMATION

The proposed scheme utilizes the Back EMF difference between two phases for BLDC sensorless drive instead of using the phase Back EMF.

2.1 Conventional Back EMF Detection Schemes

For three-phase BLDC motor, typically, it is driven with six-step 120 degree conducting mode. 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 different step is called commutation. So totally, there are 6 steps in one cycle. 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. In Fig. 1, 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, which is shown in Fig 2 (B). This scheme is quite simple.

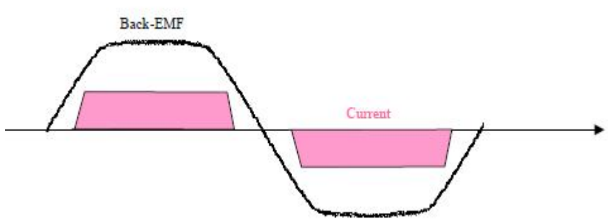

Fig 1 : The phase current is in phase with the back EMF in brushless dc motor.

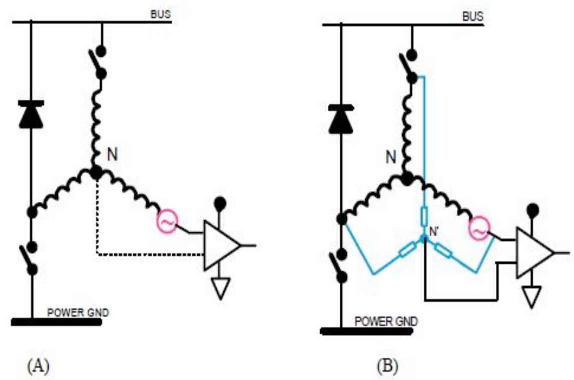

Fig 2 : (A) Back EMF zero crossing detection scheme with the motor neutral point available;
(B) back EMF zero crossing detection scheme with the virtual neutral point.

2.2 Proposed Direct Back EMF Detection Scheme

As described before, the noisy motor neutral point causes problems for the sensorless system. The proposed back EMF detection is trying to avoid the neutral point voltage. If the proper PWM strategy is selected, the back EMF voltage referred to ground can be extracted directly from the motor terminal voltage. For BLDC drive, only two out of three phases are excited at any instant of time. In the proposed scheme, the PWM signal is applied on high side switches only, and the back EMF signal is detected during the PWM off time.

Fig. 3 shows the concept detection circuit. The difference between Fig. 3 and Fig. 2 is that the motor neutral voltage is not involved in the signal processing in Fig. 3. Assuming at a particular step, phase A and B are conducting current, and phase C is floating. The upper switch of phase A is controlled by the PWM and lower switch of phase B is on during the whole step. The terminal voltage Vc is measured. Fig. 4 shows the PWM signal arrangement.

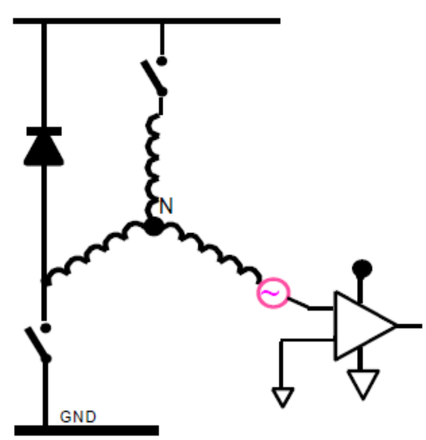

Fig 3: Proposed back EMF zero crossing detection scheme.

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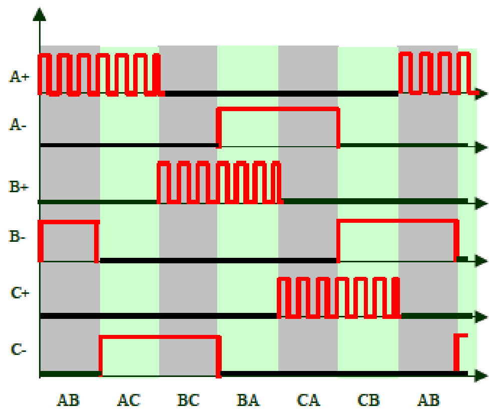

Fig 4 : Proposed PWM strategy for direct back EMF detection scheme.

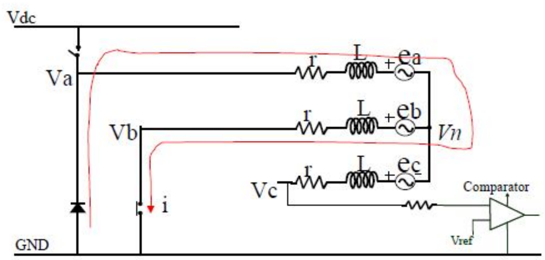

Fig 5 : Circuit model of proposed Back EMF detection during the PWM off time moment.

When the upper switch of phase A is turned on, the current is flowing through the switch to winding A and B. When the upper transistor of the half bridge is turned off, the current freewheels through the diode paralleled with the bottom switch of phase A. During this freewheeling period, the terminal voltage Vc is detected as Phase C back EMF when there is no current in phase C. From the circuit, it is easy to see vc = ec + vn , where Vc is the terminal voltage of the floating phase C, ec is the phase back EMF and Vn is the neutral voltage of the motor. From phase A, if the forward voltage drop of the diode is ignored, we have,

$$v_n = 0 - ri - L\frac{di}{dt} - e_a$$

$$v_n = ri + L\frac{di}{dt} - e_b$$

$$v_n = -\frac{e_a + e_b}{2}$$

From the above equations, it can be seen that during the off time of the PWM, which is the current freewheeling period, the terminal voltage of the floating phase is directly proportional to the back EMF voltage without any superimposed switching noise. It is also important to note that this terminal voltage is referred to the ground instead of the floating neutral point. So, the neutral point voltage information is not needed to detect the back EMF zero crossing, and we don't need to worry about the common mode voltage. Since the true back EMF is extracted from the motor terminal voltage, the zero crossing of the phase back EMF can be detected very precisely. A few tests have been conducted to show the relationship between fundamental and third harmonics. The shapes of back EMF are different from two motors. Nevertheless, the zero crossing of the third harmonics is overlapping with that of fundamental for both motors, which means that the third harmonics will not affect the zero crossing of fundamental wave. For motor B, there is slightly unbalance for three phase. Even under this situation, zero crossings of fundamental wave and third harmonic are still well overlapping.

III. SIMULATION RESULT

The closed loop controller for a three phase brushless DC motor is modeled using MATLAB/Simulink is shown in Fig. 6. Permanent Magnet Synchronous motor with trapezoidal back EMF is modeled as a Brushless DC Motor. The controller receives the actual speed signals as its input, converts it in to appropriate voltage signals. The gate signals are generated by comparing the actual speed with the reference speed. Thus a closed loop speed control is achieved with the help of PI control, present in the controller block. The three phase stator back EMF signals are input of the Zero Crossing Detector. The output of the Zero Crossing Detector is given to the PI controller, which have the inputs from the Zero Crossing Detector and actual speed of the BLDC motor. The MATLAB simulation diagram of overall are obtained for proposed concepts.

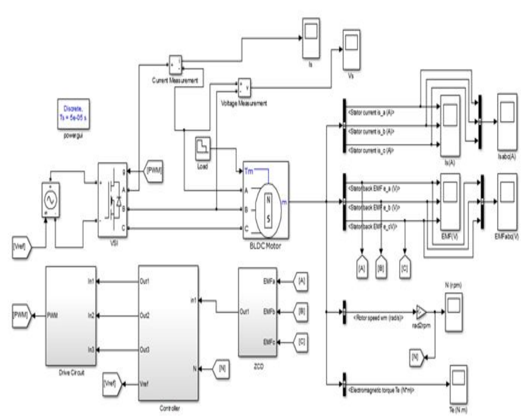

Fig 6 : Simulink Model of proposed Sensorless BLDC Drive

After aligning the rotor position to a known initial condition, the open loop start- up method is implemented to run the motor to the rated speed. By attaining the specific rated speed the BLDC motor switches to the Sensorless control where the back

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emf is detected. Fig. 7 shows the Speed Response Curve of the BLDC Motor.

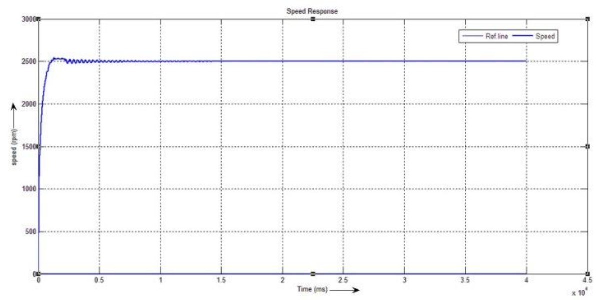

Fig 7 : Speed Response Curve of the BLDC Motor.

Fig. 8 shows the Three phase stator back emf which implies the trapezoidal waveform for the specified speed of the BLDC Motor.

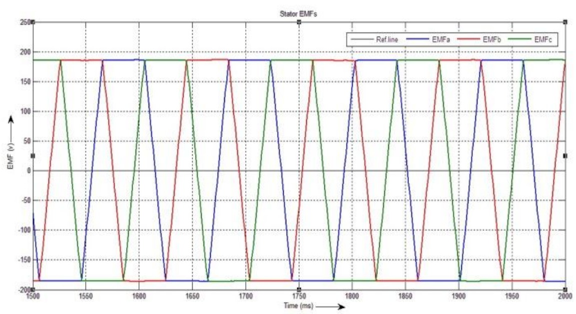

Fig 8 : Three Phase Stator Back Emf Waveform

Fig. 9 shows the Three phase stator current waveforms which intimate the magnitude of the three phase currents for the rated speed of the BLDC Motor.

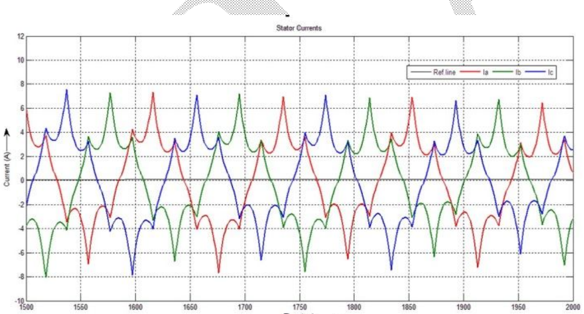

Fig 9 : Three Phase Stator Current Waveform

IV. CONCLUSION

The technology had developed in advance in appliance and automotive industry with the utilization of BLDC Motor. For compact, low cost, high reliability and low maintenance BLDC drive are more preferable in sensorless operation. Based on motor neutral point, the conventional method has its limitation on applications which was suffering from high common mode voltage noise and high frequency switching noise. A new technique is proposed in this paper by sensing back emf for BLDC Motor drive without motor neutral voltage. The major advantage the proposed technique is to detect the back emf with very high resolution and there is no filtering to cause phase shift or delay which shown in the MATLAB / SIMULINK Software.

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