INTERNATIONAL JOURNAL OF RESEARCH IN COMPUTER APPLICATIONS AND ROBOTICS
ISSN 2320-7345

SENSORLESS DRIVE FOR BRUSHLESS DC MOTOR

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Abstract: - A sensorless control method for a high-speed brushless DC motor based on the line-to-line back electromotive force (back EMF) is proposed in this paper. In order to obtain the commutation signals, the line-to-line voltages are obtained by the low pass filters. However, due to the low-pass filters, wide speed range, and other factors, the actual commutation signals are significantly delayed by more than 90 electrical degrees which limits the acceleration of the motor. A novel sensor less commutation algorithm based on the hysteresis transition between "90-α" and "150-α" is introduced to handle the severe commutation retarding and guarantee the motor works in a large speed range. In order to compensate there maining existing commutation errors, a novel closed-loop compensation algorithm based on the integration of the virtual neutral voltage is proposed. The integration difference between the adjacent 60 electrical degrees interval before and after the commutation point is utilized as the feedback of the PI regulator to compensate the errors automatically. Several experiment results confirm the feasibility and effectiveness of the proposed method.

Keywords: Brushless DC (BLDC) motor, commutation errors, line-to-line back EMF, sensorless control, virtual neutral voltage.

BLDC MOTORS:

The BLDC motor is an AC synchronous motor with permanent magnets on the rotor (moving part) and windings on the stator (fix part). Permanent magnets create the rotor flux and the energized stator windings create electromagnet poles. The rotor (equivalent to a bar magnet) is attracted by the energized stator phase. By using the appropriate sequence to supply the stator phases, a rotating field on the stator is created and maintained. This action of the rotor - chasing after the electromagnet poles on the stator - is the fundamental action used in synchronous permanent magnet motors. The lead between the rotor and the rotating field must be controlled to produce torque and this synchronization implies knowledge of the rotor position. Figure 1 shows to a brushless dc motor with a one permanent magnet pair pole rotor

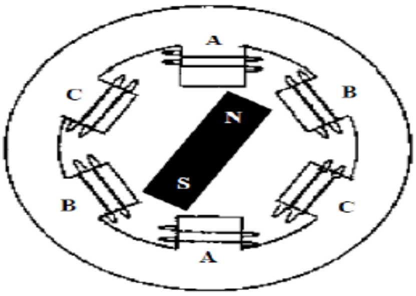

Figure 1 brushless dc motor with a one permanent magnet pair pole rotor

On the stator side, three phase motors are the most common. These offer a good compromise between precise control and the number of power electronic devices required to control the stator currents. For the rotor, a greater number of poles usually create a greater torque for the same level of current. On the other hand, by adding more magnets, a point is reached where, because of the space needed between magnets, the torque no longer increases. The manufacturing cost also increases with the number of poles. As a consequence, the number of poles is a compromise between cost, torque and volume. Permanent magnet synchronous motors can be classified in many ways, one of these that is of particular interest to us is that depending on back-emf profiles: Brushless Direct Current Motor (BLDC) and Permanent Magnet Synchronous Motor (PMSM). This terminology defines the shape of the back-emf of the synchronous motor. Both BLDC and PMSM motors have permanent magnets on the rotor but differ in the flux distributions and back-emf profiles.

BLOCK DIAGRAM

Figure 2 shows to block diagram of sensor less drive for brushless dc motor

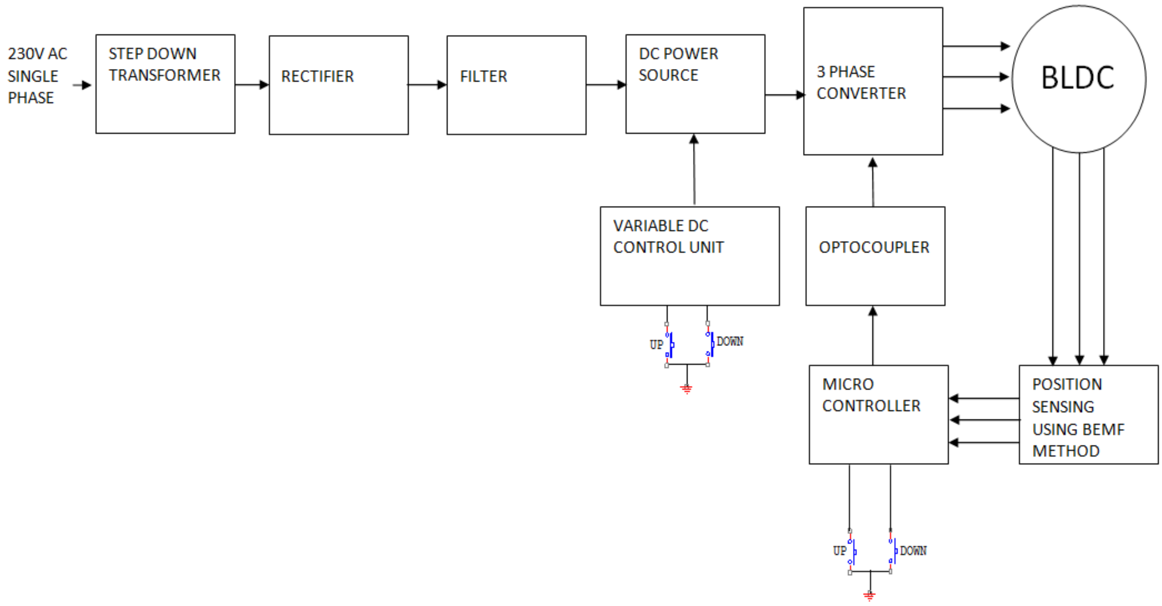

Figure 2 block diagram of sensor less drive for brushless dc motor

BLOCK DIAGRAM DESCRIPTION

1. Transformer : This block consist step-down transformer for our required ratings.
2. Rectifier : This block consist diode based rectifier Circuit
3. Filter circuit : This block consist capacitor based filter Circuit.
4. Regulator : This block consists +ve (and) – ve three Terminal regulators.

CIRCUIT DESCRIPTION:

This power supply circuit is designed to get regulated output DC voltage. The 9 volt transformer, step down the main voltage (230v) into 9 volts. The secondary voltage of transformer is rectified using bridge rectifier. The rectified unidirectional DC is smoothed by 1000mf filter capacitor. The smooth DC is then fed to the three terminal +ve regulator called 7805 to get 5v DC supply.

CIRCUIT OPERATION:

The mains voltage ac 230v is step down to 9 volt, using 9v step down transformer. The low value secondary voltage is fed to the rectifier is formed using four no. of IN 4007. For first half cycle, Diodes D1 & D2 come to action and next half cycle diode D3 & D4 come to action, finally unidirectional dc supply is fed to the filter capacitor. The charging & discharging property of capacitor provide pure smooth dc is nearly peak value of the secondary voltage. The pure DC supply is fed to regulator IC's input terminal. Due to the regulator action, finally, regulated 5 volts is available at output terminals.

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MICROCONTROLLER:

Here we are using PIC 16F877A micro controller. The PIC 16F877A is a low-power, high-performance 8-bit microcomputer with 4K bytes of Flash Programmable and Erasable Read Only Memory (PEROM).

POWER SWITCHES:

A MOSFET is a voltage controlled 3 terminal devices. There are three main terminals are the Drain, the Source and the Gate. The MOSFET (Metal Oxide Semiconductor Field Effect Transistor) is a voltage controlled device. This means that a voltage at the gate means current flows from the drain to the source.

A power MOSFET is a voltage controlled device and requires only small input current. The switching speed is very high and the switching times are of the order or nanoseconds. Power MOSFETs find increasing applications in low power high frequency converter. MOSFETs do not have the problems of second breakdown phenomena as do BJTs. However, MOSFETs have the problems of electrostatic discharge and require special care in handling. In addition, it is relatively difficult to protect them under short circuit conditions. MOSFETs require low gate energy and have a very fast switching speed and low switching losses.

OPTOCOUPLER:

The LED is a light emitting device and photo-transistor is a light sensitive device. The conduction current of phototransistor can be controlled via the conduction current of the LED, even though the two devices are physically separated. Such a package is known as an opto coupler, sine the input (LED) and the output (phototransistor) devices are optically coupled. The most important point to note about the opto coupler device is that a circuit connected to its input can be electrically fully isolated from the output circuit and that a potential difference of hundreds (or) thousands of volts can safely exist between these two circuits without adversely influencing the opto coupler action. This isolating characteristic is the main attraction of this type of opto coupler device, which is generally known as an isolating opto coupler. Refer the fig, if the output is high, then LED in IC MCT2E emits the light energy, hence photo transistor conducts & thereby Q2 conducts and the output signal to PC is low. If the output is low, then LED does not conduct and phototransistor also does not conduct which results Q2 if OFF, so, the output signals to PC is high. Typical isolating opto coupler applications include low voltage to high voltage (or vice versa) signal coupling; interfacing of a computer output signal to external electronic circuiting (or) electric motors etc. Interfacing of ground referenced low voltage circuitry to floating high voltage circuitry driven directly from the mains AC power lines etc. Opto couplers can also be used to replace low power relays & pulse transformers in many applications

OPERATIONAL AMPLIFIER DEFINITION:

An operational amplifier is a multistage, direct-coupled high-gain amplifier to which negative feedback is added, to control its overall response characteristics. Now Op-amp is used for a variety of applications, such as DC and AC signal amplification, oscillators, comparators, voltage regulators and many others.

SYMBOLIC DIAGRAM OF OPERATIONAL AMPLIFIER:

Figure shows the block diagram of a typical op-amp. There are two inputs, labeled as V1 and V2. The input voltage is V1 and V2 with respect to the ground. The output voltage is Vo with respect to ground. The output is given by,

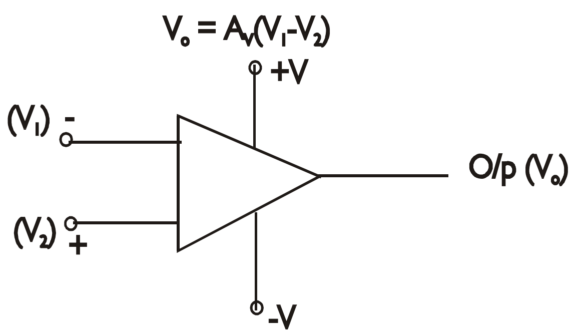

Figure 3 operational amplifier

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INVERTING MODE:

Where AV is the voltage gain of the op-amp. AV is assumed to be negative for the differential input V1-V2. It is seen that Vo is proportional to negative of V1. Hence, a signal applied as V1 is inverted (180o phase change) at the output. So V1 is called the inverting input. It is denoted by a negative sign at the terminal in the block diagram. figure 4 shows to inverting mode of operational amplifier

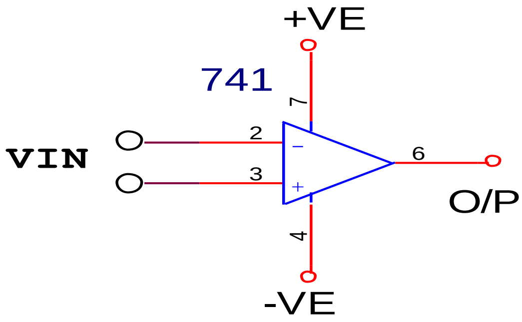

Figure 4 inverting mode of operational amplifier

NON-INVERTING MODE:

Any signal applied as the other input voltage V2 produce an output proportional to V2 and is in phase with it. Hence V2 is called the Non-inverting input. It is denoted by 'plus' sign at the terminal in the block diagram. Figure 5 shows to Non-inverting mode of operational amplifier

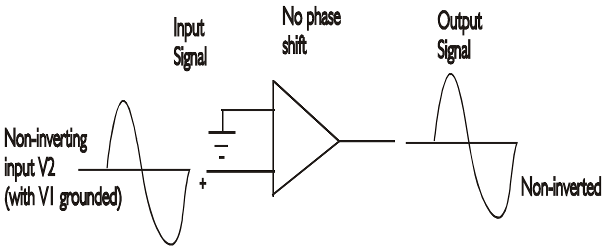

Figure 5 Non-inverting mode of operational amplifier

There is one lead common to both the inputs and the output. This is the ground lead. Since the ground lead is common to all parts of the circuit, it is often not shown in diagrams. For using the op-amp, it must be connected to a dual power supply (having +Vcc and –Vcc with respect to common earth). The actual op-amp chip has leads for the power supply. The function of the op-amp described above can be summarized as follows: If differential input Vid = (V1 – V2) is positive; the output is negative (VO).If differential input Vid = (V1 – V2) is negative; the output is positive (+VO).

The BLDC motor is characterized by a two phase ON operation to control the inverter. In this control scheme, torque production follows the principle that current should flow in only two of the three phases at a time and that there should be no torque production in the region of Back EMF zero crossings. The following figure describes the electrical wave forms in the BLDC motor in the two phases ON operation. This control structure has several advantages: Only one current sensor is necessary the positioning of the current sensor allows the use of low cost sensors as a shunt. We have seen that the principle of the BLDC motor is, at all times, to energize the phase pair which can produce the highest torque. To optimize this effect the Back EMF shape is trapezoidal. The combination of a DC current with a trapezoidal Back EMF makes it theoretically possible to produce a constant torque. In practice, the current cannot be established instantaneously in a motor phase; as a consequence the torque ripple is present at each 60 degree phase commutation. Electrical Waveforms in the Two Phase ON Operation and

Torque Ripple If the motor used has a sinusoidal Back EMF shape, this control can be applied but the produced torque is: Firstly, not constant but made up from portions of a sine wave. This is due to its being the combination of a trapezoidal current control strategy and of a sinusoidal Back EMF. Bear in mind that a sinusoidal Back EMF shape motor controlled with a sine wave strategy (three phase ON) produces a constant torque. Secondly, the torque value produced is weaker.

Figure 6 shows to torque ripple in a sinusoidal motor controlled as a bldc

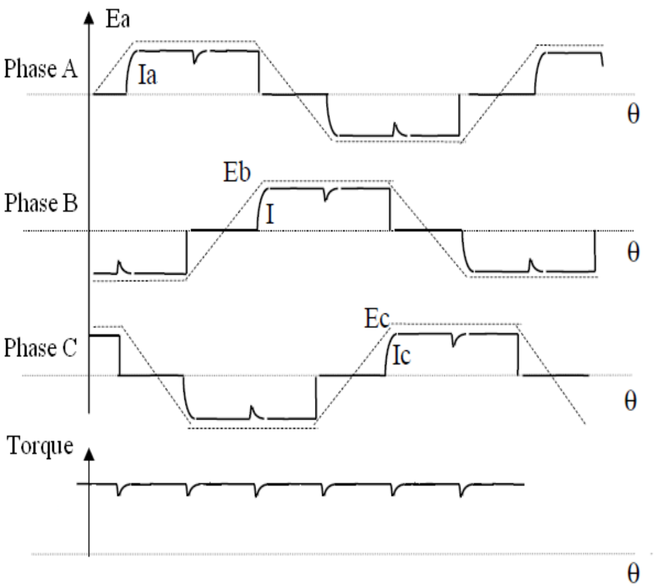

Figure 6 torque ripple in a sinusoidal motor controlled as a bldc

PULSE-WIDTH MODULATION (PWM)

Pulse-Width Modulation (PWM) are use for controlling analog circuits with a processors digital output. PWM uses a square wave whose duty cycle is modulated resulting in the variation of the average value of the waveform. PWM can be used to reduce the total amount of power delivered to a load without losses normally incurred when a power source is limited by resistive means. With a sufficiently high modulation duty cycle (D). With a sufficiently high modulation rate, passive electronic filters can be used to smooth the pulse train and recover an average analog waveform. High frequency PWM power control systems are easily realizable with semiconductor switch. The discrete on/off states of the modulation are used to control the state of the switch which correspondingly controls the voltage across or current through the load. The major advantage of this system is the switch are either off and not conducting any current, or on and have (ideally) no voltage drop across them. The product of the current and the voltage at any given time defines the power dissipated by the switch, thus no power is dissipated by the switch. Realistically, semiconductor switches such as MOSFETs or BJTs are non-ideal switches, but high efficiency controllers can still be built.

ADVANTAGES:

1. It is a long effective life.
2. It is highly reliable operation.
3. Reliable
4. Compact size
5. Affordable prize (Low cost)
6. Low Maintenance

APPLICATIONS:

It is used to industrial applications.

CONCLUSION:

The project on SENSORLESS DRIVE BRUSHLESS DC MOTOR is working fine, getting the parameter envisaged during the conceptual stage. During the design, as well as during the construction, greater care has been put into avoid hiccups at the final stage. The PCB layouts were prepared with utmost care to incorporate the circuits in a modular manner. The circuit is made as simple as to our knowledge. Also components were selected keeping in mind their availability and cost. It was a very interesting process of developing the prototype, stage by stage and testing the same. We have to go through fairly large pages of data related to the components etc. It was a useful and fulfilling assignment to get the project completed in time. This gave us a sense of satisfaction and accomplishment.

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