Sensorless Speed Control of BLDC Motor

Ambika D.[1] M. S. Aspalli[2]
[1]M.Tech. student [2]Assistant Professor
[1,2]Department of Electrical & Eectronics Engineering
[1,2]PDA Engineering College, Gulbarga Karnataka

Abstract— Brushles DC motor are one type of motors that are rapidly gaining the popularity and are penetrating in industrial applications, home appliances, automotive, consumer, medical etc. Because of there many advantages such as high efficiency ,silent operation, compact form ,reliability, low maintenance (due to the absence of brushess), long operating life, high speed ranges etc. for the proper commution of current in inverter the rotar position information is necessary, this information is usually provided by the mechanical position sensors mounted within the motor. however it is well known that these position sensors have many drawbacks therefore a sensor less control of BLDC motor is developed which eliminates the sensing equipment ,reduces the cost of motor and increases the reliability of the BLDC motor. In this paper the position information is obtained from the zero crossing detection of the back EMF which is also called as the terminal voltage sensing method which is the simplest ,method of detecting the back EMF zero crossing ,here the motor voltages are sensed and give to the lowpass filter whose output is give to the ZCD which determines the zero crossing of the back EMF waveform and ZCD generates the signal required for the controller to provide the pulses for the inverter operation the controller used is a high performance controller(DSPic30F4011) which as both the features of microcontroller and digital signal processor .The complete model is simulated in MATLAB/SIMULINK software. the proposed hardware and simulation program are found to be efficient and the results are promising

Keywords: ZCD, MATLAB, SIMULINK

I. INTRODUCTION

Due to the advancement in permanent magnetic materials, solid state devices and microelectronics have resulted in new energy efficient drives such as Brushless Dc motor. Energy saving as been one of the important issues in home appliances hence a lot of efforts have been made to reduce the energy consumed by the home appliances such as refrigerators air conditioners ,cloth washers ,vacuum cleaners etc .these appliances typically rely on Electric motor technologies such as DC motor, induction Motors, capacitor Start universal motors etc and consumers are demanding for the reduce noise, better performance and Low cost motors .However the above mentioned technologies cannot meet the consumer demands .the only motor which fulfills the needs of the consumer is the Brushless Dc motor for this reason the Brushless Dc(BLDC)motors are gaining much popularity in recent years .Brushless Dc motor offer many advantages compared to DC motor and Induction motor Some of the advantages are Speed versus torque characteristics which is Flat in case of brushless Dc motor ,higher speed ranges due to the absence of brushes or commutators, high reliability, high dynamic response low electrical noise generation, longer life etc .

Brushless DC motor with their trapezoidal back EMF profile requires six discrete rotor position information to properly perform the phase commutation and /or current control. These are typically generated by the mechanical position sensors such as Hall Effect sensors, shaft encoders or resolvers that are mounted within the motor. However the known fact is that these mechanical position sensors have many disadvantages such as

(1) They increase the cost of the motor.
(2) Need special mechanical arrangement and
(3) They are temperature sensitive; hence reduce the reliability of the motor because of the extra component and wiring [4].

Hence the only reliable way to overcome all the above mentioned disadvantages or drawback of the sensors is the sensor less control of the motor. The BLDC motor without position sensor have attracted wide attention and many paper have been reported on this .The methods are based on the using the back EMF of motor[10].back EMF estimation method rely on zero crossing of the back waveform. The technique of estimating the zero crossing of back EMF from line voltage difference implemented using DSP is proposed in [4].since all the three line voltage difference should be taken the method is complex as they used digital signal controller for the implementation . Instead of measuring all the motor terminal voltages ,the rotor position information is extracted from only one of the three motor terminal voltages for the three phase BLDC motor implemented using a microprocessor is proposed in [6].the commutation instant of the BLDC motor can also be estimated using the third harmonic integration of the back EMF waveform[5] as method as the advantages such as the simplicity of implementation less filtering ,allows wide speed range of operation but the variation of the amplitude.

and phase of harmonic component due to magnetic saturation are the limitations of the third harmonic technique, and also the low value of the stator third harmonic voltage at low speed cause serious position error and make this technique less suited for the low speed range applications.[3],in this paper the torque constant of the BLDC motor is used as the reference signal for the position detection. And this is estimated by calculating the ratio of back EMF to rotor speed ,here the rotor speed is obtained from the disturbance observer, this disturbance observer cannot give direct rotor speed ,as it requires the speed error thus additional algorithm is required to obtain the speed error due to this there are the parameter errors and hence these must be compensated to achieve the more accurate speed estimation and the block diagram looks more complicated than the conventional algorithm. the commutation instant can also be calculated by taking the derivatives of the three motor terminal voltages[12],the method is quite robust but it involves the decomposition of

All rights reserved by *www.ijsrd.com*

the phase currents and the back EMF by the Fourier transformation. the detection of conducting state of freewheeling diode is one of the method to detect the rotor position ,this approach works over wide speed range especially at low speed .the main drawbacks is the requirement of the six additional power supplies for the comparator circuits to detect the current flowing through the freewheeling diode [4].This paper proposes a simple and reliable method where the rotor position information is obtained from the back EMF Zero crossing detection, this proposed method does not involve any integration and derivatives as described in[6]-[8] .the organization of the paper is as follows section II describes the background of Back EMF method .section III presents the proposed method .section IV presents the simulation results and section V presents the hardware implementation results that validate the proposal and conclusion is presented in section VI.

II. Background Of Back Emf

When the BLDC motor rotates, each winding will generates the voltage known as back electromotive force or simply back EMF .which opposes the main voltage supplied to the windings according to the Lenz law. The polarity of this back EMF is in opposite direction to that of the energized voltage, back EMF mainly depends on three factors

(1) Angular velocity of the motor
(2) Magnetic field generated by the rotor magnets
(3) The number of turns in the stator windings.

Back EMF is expressed as

$$\text{Back EMF} = N\, l\, r\, B\, \omega \qquad 1.1$$

Where
N is the no of windings per phase
l is the length of the rotor
r is the internal radius of the rotor
B is the rotor magnetic field density and
ω is the motor's angular velocity.

From the above equation the only variable term is the rotor angular speed .therefore the back EMF is directly proportional to the rotor speed ,as speed increases the back EMF increases and vice versa.

III. Proposed Back Emf Zero Crossing Detection Method

This method is one of the simplest methods of back EMF sensing techniques for obtaining the rotor position information and is based on the detection of the detection of zero crossing of the back EMF waveform. In the typical operation of the BLDC motor,the phase current and back EMF should be aligned to generate the constant torque [3] .for six step commutation of the BLDC motor through a three phase inverter for driving the BLDC motor the conducting interval of each phase is 120 electrical degrees. therefore at any instant only two phases will conduct current, leaving the third phase floating in order to produce maximum torque.

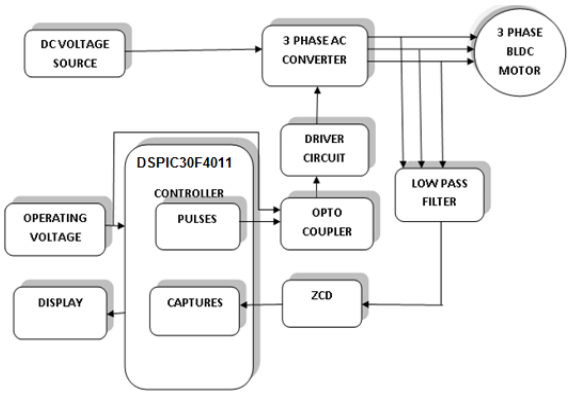

Fig. 1: Block diagram of proposed system.

The Direct current (DC) voltage source is applied to the three leg of the three phase inverter which consist of six MOSFET switches used for the commutation of the current this converter will convert the DC into Alternating current(AC) which is required to run the BLDC Motor and parallel the output of the inverter is given to the Low pass filter made up of the inductor and capacitor this low pass filter will convert the trapezoidal voltage waveform were many times the signal crosses zeros into the pure sinusoidal waveform were the signal crosses the zero only once. This is conversion is needed because of the Zero crossing detector .The output of this low pass filter after isolation is given to the Zero crossing detector (ZCD) this ZCD consist of the operational amplifier which is programmed to detect the zero crossing of the back EMF signal. Whenever the back EMF wave crosses zero the op amp will give a signal which is purely a square wave required for the controller to perform the pulse generating function. Depending on the signal given by the ZCD, controller reads the captures (signals equivalent to the hall sensor signals) and the corresponding PWM pulses are generated in the DSPIC Controller. These pulses are also given to the liquid crystal display in order to view and the pulses are isolated using the Opto coupler. The Output of the Opto coupler pulse is inverted pulse of the input, but we want same pulse generated from the controller. That's the reason for we are choosing NOT gate IC. And it is introduced into the output of the Opt coupler and then the output of the NOT gate is given to the input of the driver IC. The driver IC nothing but high stage buffer IC and the output are given to three phase converter (switch as MOSFET).therefore by giving the proper commutation sequence the speed of the brushless DC motor is controlled. . However the back EMF is Zero at Standstill hence the brushless DC motor is Self Started by energizing all the three motor windings with 120° Phase shift. Each blocks are explained as follows

A. Inverter circuit

The inverter consists of a single leg MOSFET circuit (Half bridge). MOSFET (IRF840) switch is used as a switching device .the DC voltage source is given to the three legs of the three phase inverter. The PWM signals from the driver IC is fed to the gate of the MOSFET switch as explained above .the output of the inverter circuit is given to the motor.

B. Low pass filter:

The motor terminal voltages after sensing are fed into the low pass filter to suppress the high switching frequency

All rights reserved by *www.ijsrd.com*

ripples or noise .the output of this is a pure sine wave which is given to the ZCD.

C. Zero Crossing detectors

The ZCD will convert the sine wave obtained from the low pass filter into a square wave that is analog signal is converter into digital signal. This conversion operation is performed by the operational amplifier IC .this op amp will detect the zero crossing of the back EMF waveform and generate the corresponding waveform required for the controller.

D. Controller (DSPic30F4011).

The controller used to control the speed of BLDC motor is the DSPic30F4011 which as many advantages compared to other controllers. This DSPic controller will read the square wave and generates the pulses required for the inverter operation.

E. Optocoupler

The main function of the optocoupler is to isolate the control circuit and the power circuit .The PWM signals from the controller are not directly given to the power circuit. If this isolation is not provided then the power components may damage and lead to the mis operation of the circuit.

F. Driver circuit

The MOSFET diver circuit is designed to connect the gate directly to a voltage bus with no intervening resistance other then the impedance of the driver circuit switch. The gate driver acts as a high power buffer stage between the PWM output of the control device and the gate s of the power switching MOSFET.

IV. Simulation Results

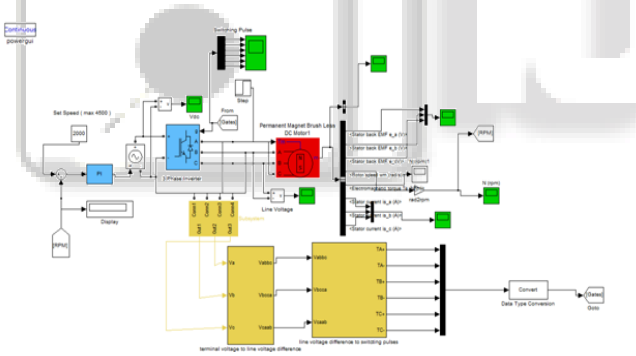

Fig. 2: Simulation Block Diagram of the proposed system.

The proposed sensor less speed control of BLDC motor is simulation Block diagram is shown in the fig and is simulated using SIMULINK MATLAB software. The simulation is done for the variation of set speed range from 0 to 3000 RPM .The Output of the BLDC motor are fed to the subsystem which is made up of measurement block in order to obtain the rotor position for the proper commutation of the phase current and or current control, the terminal voltages are first converted into the line voltage and there difference is taken and then these line voltage difference is used to obtain the pulses required for the inverter operation. In this the three motor terminal voltages R,Y and B generated after the motor is started is shown in the fig a[waveform]. The corresponding back EMF waveform for all the three phase is shown in fig b. rotor speed is shown in fig c and the torque of the motor in fig d.

V. Hardware And Experimental Results

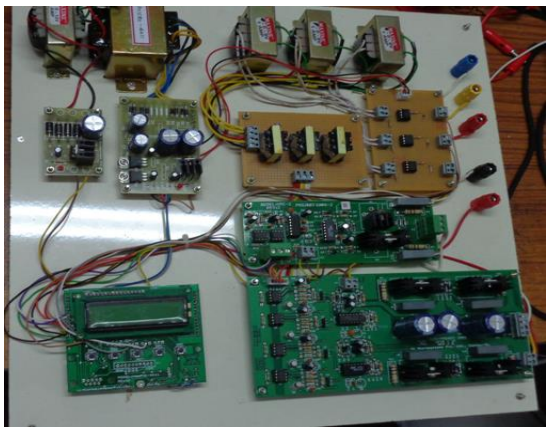

Fig. 3: Complete Hardware set up.

The hardware used for the proposed sensor less control method consist of inverter circuit ,control circuit ,isolation circuit for protection purpose and power supply circuit. The fig shows the complete hardware set up for the sensor less control of the BLDC motor. The motor specification used for the project are given the table I.The waveforms shown below are the results obtained from the proposed sensor less control method gate pulses, back EMF waveforms rotor speed and torque of the motor taken using the digital signal oscilloscope. For closed loop the speed is set according to our requirement and is the corresponding actual speed is noted down and corresponding current during this operation is observed to be 0.37 and will vary according to the duty cycle and motor actual speed is noted. In the open loop operation of the proposed sensor less control method the duty cycle of the PWM pulses is varied between 20% to 80%(max 82%).

Type of motor	BLDC Motor
Voltage rating	24V
Power rating	60watts
Speed	3000rpm
No. of poles	8
Degree	120^0

Table 1: Specifications of Bldc Motor

VI. Waveforms

Fig. 4: Lowpass filter output

All rights reserved by *www.ijsrd.com*

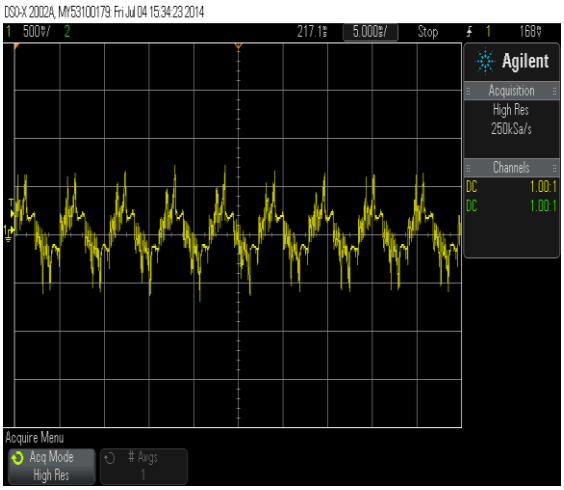

Fig. 5: Stator current of R phase

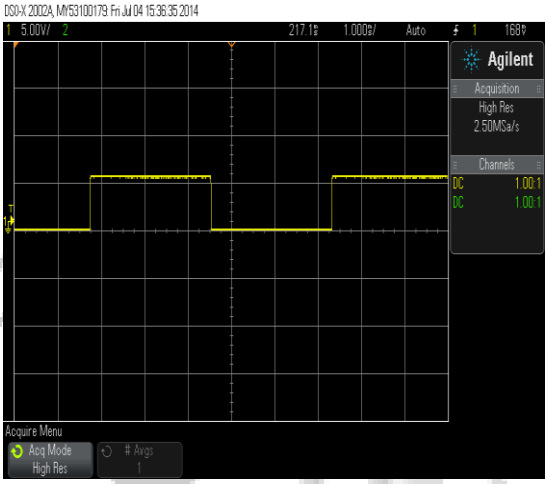

Fig. 6: ZCD output of B Phase

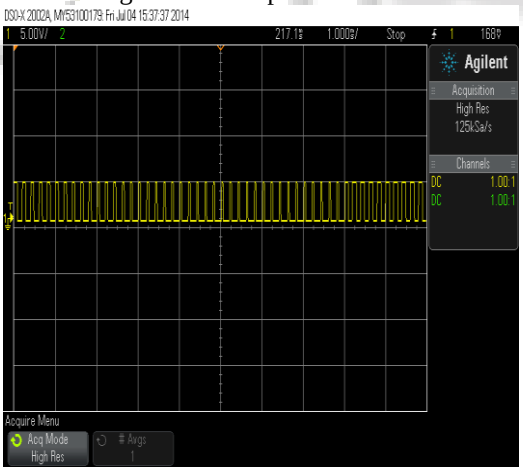

Fig. 7: Pulse Width Modulation signal

VII. CONCLUSION

This paper has proposed a new cost effective and easy sensor less control scheme for the speed control of the BLDC motor based on the zero crossing detection of the back electromotive force .The proposed method is implemented on the motor of rating 24V, current 2.3 A, power 60 W, 3000 rpm, 8 poles and is programmed using the DSPic30F4011 microcontroller this controller will generate the necessary pulses required for the inverter operation depending on the set speed and the actual speed obtained from the back EMF waveform. The switches used in the inverter are the MOSFET which have many advantages compared to BJT and IGBT.the program and the results obtained are promising .The motor is found to run smoothly and sensor less.

REFERENCES

[1] PadmarajaYedamale, **"**AN885: Brushless DC Motor Fundamentals"**,** Microchip TechnologyInc 2003
[2] Anand Sathyan,Mahesh Krishnamurthy, Nikola Milivojevic & Ali Emadi "A Low-Cost Digital Control Scheme for Brushless DC Motor Drives in Domestic Applications", IEEE,2009.
[3] Je-Wook Park, Student Member, IEEE, Seon-Hwan Hwang, Member, IEEE, and Jang-Mok Kim, Member, IEEE "Sensorless Control of Brushless DC Motors With Torque Constant Estimation for Home Appliances" IEEE Transaction on industry applicationsvol 48,no2, march/april 2012
[4] P.Damodharan and Krishna Vasudevan, Member, IEEE "Sensorless Brushless DC Motor Drive Based on the Zero-Crossing Detection of Back Electromotive Force (EMF) From the Line Voltage Difference" IEEE transactions on energy conversion ,vol.25,no.3,sep 2010.
[5] Ashish P.R and Vincent Sensor less control of BLDC motor using third harmonic back EMF.
[6] Gui-Jia Su and John W. McKeever " Low-Cost Sensorless Control of Brushless dc Motors with Improved Speed Range Oak Ridge National Laboratory National Transportation Research Center 2360 Cherahala Blvd. Knoxville, Tennessee 37932.
[7] P. Devendra, Madhavi TVVS, K Alice Mary, Ch. Saibabu, "Microcontroller based control of three phase BLDC motor", Journal of Engineering Research & Studies/Volume II/Issue IV, October-December 2011.
[8] Preetha Philip1, Dr. Meenakshy K2 1M.Tech Student,2Associate Professor, Dept. of Electrical Engg. Govt. Engineering College **"** Modelling Of Brushless DC Motor Drive Using Sensored And Sensorless Control(back EMF zero crossing detection)", Thrissur International Journal of Emerging Technology and Advanced Engineering, Volume 2, Issue 8, August 2012.
[9] Juan W. Dixon, Matías Rodríguez and Rodrigo Huerta"Simplified Sensorless Control for BLDC Motor, Using DSP Technology",
[10] Geethu Zacharia and Annai Raina "A Survey on Back EMF sensing methods for sensor les brushless DC motor drives"international journal of emerging trends in engineering research vol 2,no .2,feb 2014.
[11] S.Joshuwa, Satishkumar and Ramsankar " Advanced rotar position detection technique for sensorless BLDC motor control"International journal of soft computing and engg vol-2,issue –I march 2012
[12] Abdelali boughaba,Mabrouk Chaabane and Said Benaggoune "Robust sensor less control of BLDC motor using Second derivative function of the sum of the terminal voltages" SERBIAN Jouurnal of electrical engineering vol -10 no-2,june 2013,275-291

All rights reserved by *www.ijsrd.com*