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Modelling of 3 Phase 4-Switch Inverter Fed BLDC Motor

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ABSTRACT:This paper describes modelling of four switch inverter fed BLDC motor, is explained with transfer function model. The simulation of sensor will be done in MATLAB/Simulink and sensor less control of drive will also be done in MATLAB/Simulink. Control with sensor, the controller is used Fuzzy logic Controller/PID Controller and in sensor less control the method is used is terminal voltage sensing. To improve sensor less control performance, four-switch electronic commutation modes based proportional integral controller scheme is implemented. In three phase 4-switch inverter reduction of switches, having reduced in cost and saving of hall sensor were incorporated. The feasibility of the proposed sensor less control four-switch three phase inverter fed brushless DC motor drive is implemented, analyzed using MATLAB/SIMULINK, effective simulation results have been validated out successfully.

KEYWORDS: Brushless DC Motor (BLDC) ,Neuro Fuzzy based PID Controller , Four Switch Inverter, speed control method, sensor &sensorless control..

I.INTRODUCTION

Permanent Magnet (PM) brushless DC machines has various advantage such as high efficiency , high power factor,high torque , simple control,lowcost,simplecircuitary& less maintenance. Thera are two types of DC motor used (1) conventional DC motor in which flux is produced bu the stationary field pole coil current (2) Brushless DC having perment magnet produce the flux in wire wound field pole. The commutator is used in conventional DC motor , in brushless the commutator is replaced by electronically commutation.In this paper NFPID controller is applied in speed control of PMBLDC motor, For improvement of the NFPID controller Kp,Ki&Kd can be utilised by proper proportional. The PMBLDC widely used in aerospace,militarypurpose,electricautomative,refrigeration,computer,house hold appliances. The functions of commutator and brushes are implemented by solid state switches , maintenance free motors called the Brushless DC motor are developed. Latest developments in power electronics, microelectronics and modern control technologies have greatly affected the wide spread use of permanent magnet DC motors. The roughly Classification of Permanent Magnet motors are permanent magnet synchronous motor (PMSM) and Permanent Magnet Brushless DC motors (PMBLDCM). The PMSM has sinusoidal back-emf waveform the BLDC motor has trapezoidal back-emf waveform. PMBLDC motors have superior over brushed DC motors and induction motors, like better speed-torque characteristics, high dynamic response, high efficiency, high power factor, noiseless operation , simple circuitary and wide flexibility in speed ranges. The specific torque is higher enabling it to be used in applications where space and weight are diverse factors. An advanced microcontrollers and electronics has overcome the challenge of implementing required control functions, making the BLDC motor more familar for a wide applications.
Due to the advance of the BLDC motor come at the expense of increased complexity in the electronic controller circuitary and the accurate shaft position sensing. Permanent magnet (PM) excitation is more famous in smaller motors upto below 20 kW. In above 20 KW motors, the cost and weight of the magnets become increased and it would required additional circuitary for excitation by electromagnetic or induction . However, the development of high-field PM materials, PM motors with ratings encourages to built of a few Megawatts motors

II.LITERATURE REVIEW

[1] M.Vigneshkumar ‘‘Simulation Modeling of Inverter Controlled BLDC Drive Using Four Switch ”International Journal of Scientific & Engineering Research 351-356 Volume 4, Issue 5 May 2013.
Observation: This paper gives the idea about permanent magnet Synchronous motor drive for automotive application Permanent Magnet Synchronous Motor (PMSM’s) is used in many applications that require rapid torque response and high – performance operation. Due to several new applications, these motors are quite popular & use in a developing country such as India for Automotive application. In a permanent magnet synchronous motor, the dc field winding of

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the rotor is replaced by a permanent magnet. Classification and application of Permanent Magnet AC motor, operating principle, Permanent magnet synchronous motor (PMSM) drive.

[2] M. B. de Rossiter Correa, C. B. Jacobina, E. R. C. da Silva, and A. M. N. Lim, "A general PWM strategy for four-switch three-phase inverters", IEEE Trans. Power Electron., vol. 21,no. 6, pp. 1618–1627, Nov. 2006.

Observation: This paper presents a method to generate PWM signals for control of four-switch three-phase inverters. With the proposed approach, it was possible to study several PWM schemes using three or four vectors to synthesize the desired output voltage during the switching period. The effect of Star and delta motor winding connections over the pulse width modulator is also considered. The common mode voltage generated by the four-switch three-phase converter is evaluated and compared to that provided by the standard six-switch three-phase inverter.

[3] B.-K. Lee, T.-H. Kim, and M.Ehsani, "On the feasibility of four-switch three- phase BLDC motor drives for low cost commercial applications: Topology and control," IEEE Trans. Power Electron., vol. 8, no. 1, pt. 1, pp. 164–172, Jan. 2003.

Observation: This paper presents an analytical study on commutation torque ripple in a four-switch brushless DC motor drive. The analytic equations of commutation intervals and commutation torque ripple are obtained for each mode. Developed results show that phase commutation characteristics are different for each operation modes. It shows also the limit point of current control reduced to half of its corresponding point in a six-switch inverter. It means the accessible speed range that the phase currents can be regulated as rectangular is limited to half of nominal speed. The proposed method enhances the performance of the FSTPI-BLDC motor drive and can be used for low cost applications.

[4] A. HalvaeiNiasar, H.Moghbelli, and A. Vahedi, ''Sensorless control of a four-switch, three-phase brushless DC motor drive,'' presented at the Iranian Conf. Electr. Eng. (ICEE 2007), May, Iran Telecommun. Res. Center (ITRC), Tehran, Iran.

Observation: This paper proposes a position Sensorless control scheme for four-switch three-phase (FSTP) brushless dc (BLDC) motor drives using a field programmable gate array (FPGA). A novel Sensorless control with six commutation modes and novel pulse width modulation scheme is developed to drive FSTP BLDC motors. The experimental results show that the scheme works very well. With the developed control scheme and the lowest cost implementation, the proposed scheme is suitable for commercial applications.

[5] A. HalvaeiNiasar, "Sensorless control of four switch, three phase brushless DC motor drives for low-cost applications," Ph.D. dissertation, Dept. Electr. Eng., Iran Univ. Sci. Technol., Tehran, Iran, Dec. 2007.

Observation: This paper proposed a low-cost BLDC motor drive is introduced in this study. Cost saving is achieved by reducing the number of inverter switches and also elimination of the position Hall Effect sensors. The DPC control technique is used for the four-switch converter, which leads to the same characteristics as the six switch converter. The proposed method has several advantages.

III.PROJECT METHODOLOGY

A brushless DC motor (BLDC) is asynchronous electric motor which is powered by direct current electricity (DC) and has an electronically controlled commutation system, instead of a mechanical commutation system with brushes. It has all the good advantage of DC drives and eliminating the drawbacks using electronic commutation. So in this motor current and torque, voltage and rpm are related linearly. Normally from the Hall Effect sensor, the signal for commutation is generated. But using these sensors the size of the BLDC motor will become larger and when space will be a main constraint, BLDC motor fails to meet the same. BLDC Motors are extensively used in domestic and automobile industries.

A. With Sensor Control:

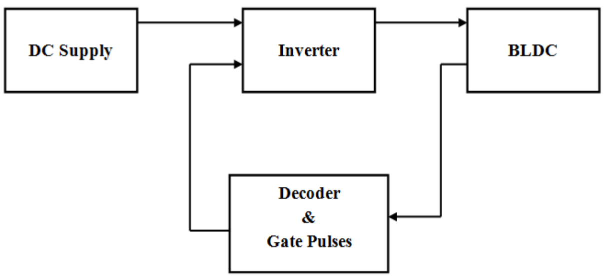

Figure 1: Block Diagram of Sensor less Control

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Cost reduction in BLDC motor drives can be achieved by two methods one topological approach and second control approach. In the topological approach, the number of switches, sensors and associated circuitry used to compose the power converter is minimized. Normally for the BLDC Motor drive six switches inverter topology is used. By reducing the no of switches the cost reduction can be achieved. Moreover switching and conduction losses can be reduced. So here Four Switch VSI (FSVSI) topology is attempted. By using the Sensor less control the cost of the sensors are also eliminated. Modeling of the BLDC machine and the controller are essential for evaluating their performance. Each of the simulators allows setting of the input parameters. In this work the modeling of BLDCM is explained with transfer function model. The simulation of sensor and sensor less control of drive is done in MATLAB/Simulink. Control with sensor, the controller is used by Fuzzy / PID Controller and in sensor less control the method is used terminal voltage sensing.

Permanent magnet motors with trapezoidal back EMF and sinusoidal back EMF have several advantages over other motor types. Most notably, (compared to dc motors) they are lower maintenance due to the elimination of then mechanical Commutator and they have a high-power density which makes them ideal for high-torque-to weight ratio applications. The permanent magnet brushless dc (BLDC) motor is gaining popularity being used in computer, aerospace, military, automotive, industrial and household products because of its high torque, compactness, and high efficiency. A conventional BLDC motor drive is generally implemented via a six switch, three-phase inverter and three Hall-effect position sensors that provide six commutation points for each electrical cycle. Cost minimization is the key factor in an especially fractional horse-power BLDC motor drive for home applications. It is usually achieved by elimination of the drive components such as power Switches and sensors. Therefore, effective algorithms should be designed for the desired performance. Recently, a four switch, three-phase inverter (FSTPI) topology has been developed and used for a three-phase BLDC motor drive. Reduction in the number of power switches, dc power supplies, switching driver circuits, losses and total price are the main features of this topology. It results in the possibility of the four-switch configuration instead of the six switches. Compared with the four switch converter for the induction motor, it is identical for the topology point of view. However, in the four-switch converter, the generation conducting current profiles isinherently difficult due of 120˚ to its limited voltage vectors. This problem is well known as "asymmetric voltage PWM". It means that conventional PWM schemes for the four-switch induction motor drive cannot be directly used for the BLDC motor drive. Therefore, in order to use the four-switch converter topology for the three-phase BLDC motor drive, a new control scheme should be developed. The solutions can be obtained from a modification of the conventional voltage controlled PWM strategies, such as the space vector PWM. However, it naturally requires lots of equations for the transformation of voltage and current vectors, α-β and a–b–c frames. As a result, the current control such as block becomes much more complicated. Moreover, in order to handle the complicated calculations in one sampling period, a high-speed digital processor is also necessary, which increases the manufacturing cost. Therefore, for the low cost BLDC motor applications, voltage vector PWM schemes cannot be regarded as a good solution for cost effective purpose. Modeling and simulation of electromechanical systems with BLDC drives are essential steps at the design stage of such systems. For the purposes of stability analysis and controller design, it is often desirable to investigate the large-signal transients and small-signal characteristics of the system. Simulation studies are also often performed many times to achieve the required design goals. In his study, the nonlinear simulation model of the BLDC motors drive system with PI control based on MATLAB/Simulink platform The simulated results in terms of electromagnetic torque and rotor speed are given.

B. PI CONTROLLER

Two controllers are incorporated: PI controller for speed control and P controller for current control. The feedback measures the actual speed and subtracted from reference speed and error is given as input to the speed PI controller and output of the PI is subjected to current limiter and that acts as current reference from which actual current is subtracted and error is given input to the current P controller. This output of the PI is the dc value that is compared with a continuous triangular pulse of 40 kHz. The output is varying duty cycle that is added with gate pulse to produce a pulse-modulated wave, which triggers the inverter to generate required voltage to maintain the speed at varying load torques and speed reference conditions.

C. FUZZY LOGIC CONTROLLER

Fuzzy logic controller is used for simulation of BLDC Motor with sensor. Three hall effect sensors are connected the other end of the motor and they are separated by 120 degree mechanically. A Fuzzy Logic Controller (FLC)[11-12] uses fuzzy logic as a design methodology, which can be utilized for developing linear and non-linear systems for embedded

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control. FLC techniques need less development time, have better performance and are good replacements for conventional control techniques, which require highly complicated mathematical models. A fuzzy logic controller does not require an exact mathematical model. It however requires knowledge-based set of heuristic rules. These rules variables. The steps involved in the design of fuzzy controller are fuzzification, rule definition and defuzzification.

For the fuzzy controller necessary data required for the simulation is given in Table 1. The two inputs given are error and change in error. The output is the reference current for the Hysteresis controller. All three membership functions are Triangular. The input and output membership functions are shown in Figures 10 to 12. The fuzzification rule is entered using the rule editor of the fuzzy toolbox as shown in Figure 13. The simulation diagram is shown in Figure 14. The overall simulation diagram with controller, four-switch inverter and BLDC motor model.

Parameters	Values
No. of Poles	4
Power	2Hp
Input Voltage	415
Stator Resistance per phase	1.5 ohm
Stator Inductance per phase	8.5 mH
Torque Constant	1.4 Nm/Apeak
Voltage Constant	146.077 VpeakL-L/krmp
Moment of Inertia	0.008 kgm^2
Friction Coefficient	0.01 Nms

Table 1. Parameters of Motor

IV.MATLAB SIMULATION MODEL

FUZZY LOGIC CONTROLLER

The fuzzy logic Controllers are basically put to use when the system is highly non-linear there by making the making the mathematical modeling of the system very arduous. The analytical form of the system is not provided, a linguistic form is provided.

The precise identification of the system parameters are required . The (FLC) Fuzzy Logic Controller uses fuzzy logic as a design methodology. There are basically three essential segments in Fuzzy Logic Controller. They are Fuzzification block or FuzzifierSystem.Defuzzification block or Defuzzifier. This is shown in figure .The first step towards designing a Fuzzy Logic Controller is choosing appropriate inputs which will be fed to the same .These input variables should be such that , they are represent the dynamical system completely. The two inputs given are error and change in error .The output is the reference current for the Hysteresis controller . All the three membership functions are Triangular. The input and output membership functions are shown in Figures 31 to 32. For the fuzzy controller necessary data required for the simulation is given in Table 1. A Defuzzifier is generally required only when the Mamdani Fuzzy Model is used for designing a controller. Mamdani model is preferred here because it follows the Compositional Rule of Inference strictly in its fuzzy reasoning mechanism. Unlike the Mamdani model, the outputs are defined with the help of a specific function for the other two models (first order polynomial in the input variables) and hence the output is crisp instead of fuzzy. This is counterintuitive since a fuzzy model should be able to propagate the fuzziness from inputs to outputs in an appropriate manner. The inference system of a Fuzzy Logic Controller consists of a number of IfThen rules. If side of the rule is called the antecedent and then side is called the consequence. These rules are very simple to understand and write and hence the programming for the fuzzy logic controller becomes very simple. The fuzzification rule isentered using the ruleeditor of the fuzzy toolbox as shown in Figure 12. Simulink model has the BLDC model, Block diagram of the FLC for the speed control of the PMBLDC, the gate pulses from the PWM Gate block. This block in turn receives two inputs –switching signal generated from encoder and duty cycle generated from the fuzzy controller block.

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The step change in speed reference and load is given at the pre-specified time. The controller performance is tracked by observing the speed after the input command. The measured motor speed from the BLDC drive is compared with the reference speed producing the error which is given to the controller in the model. By decoding output of the hall sensor signals, gate pulses for the three phase inverter are generated. The current output from the fuzzy output is fed to hysteresis controller (current limit control) is used for making the phase currents smoother. Simulation results are shown in Figure

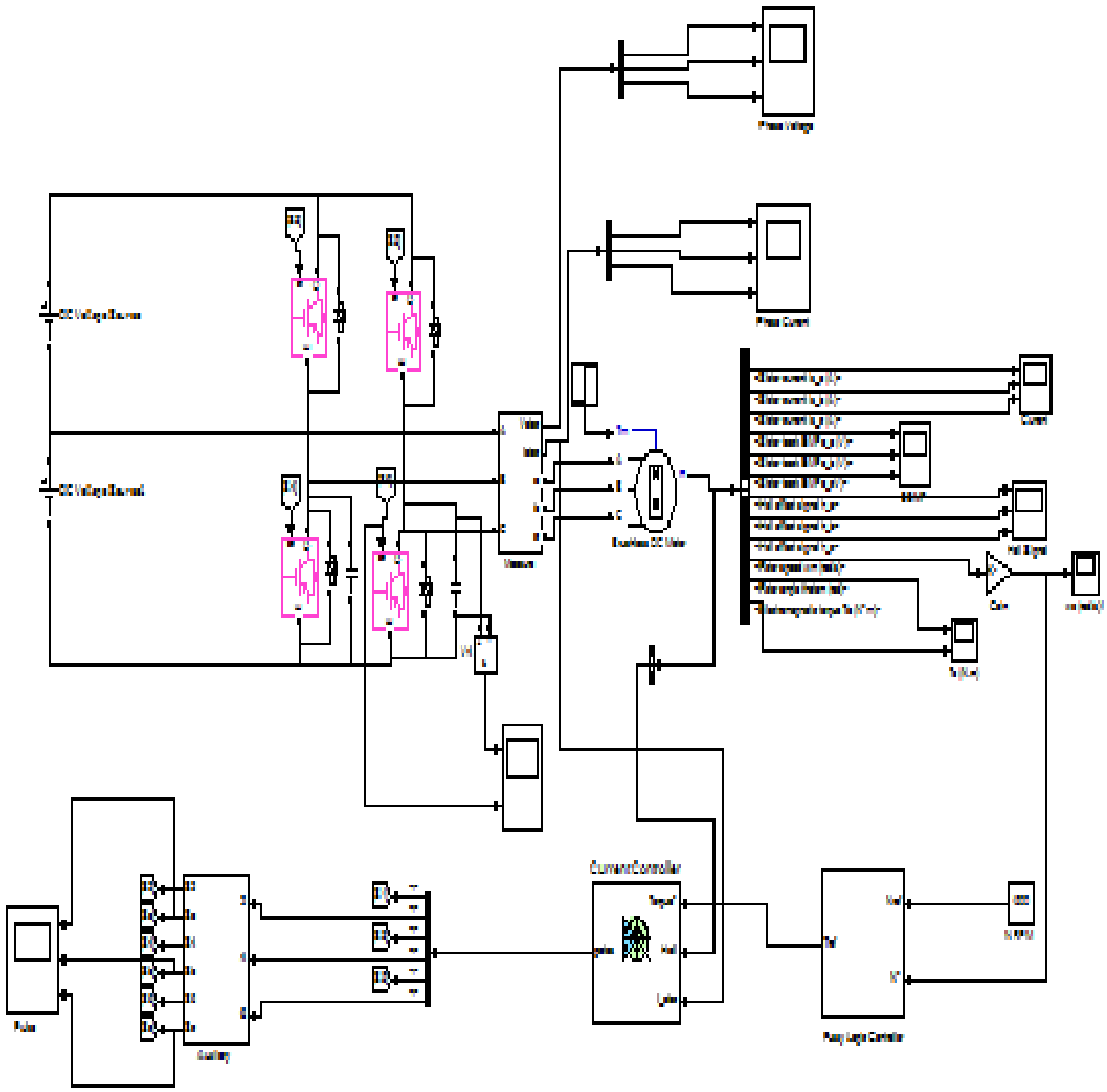

Figure 2.. Simulation diagram of BLDC motor with error

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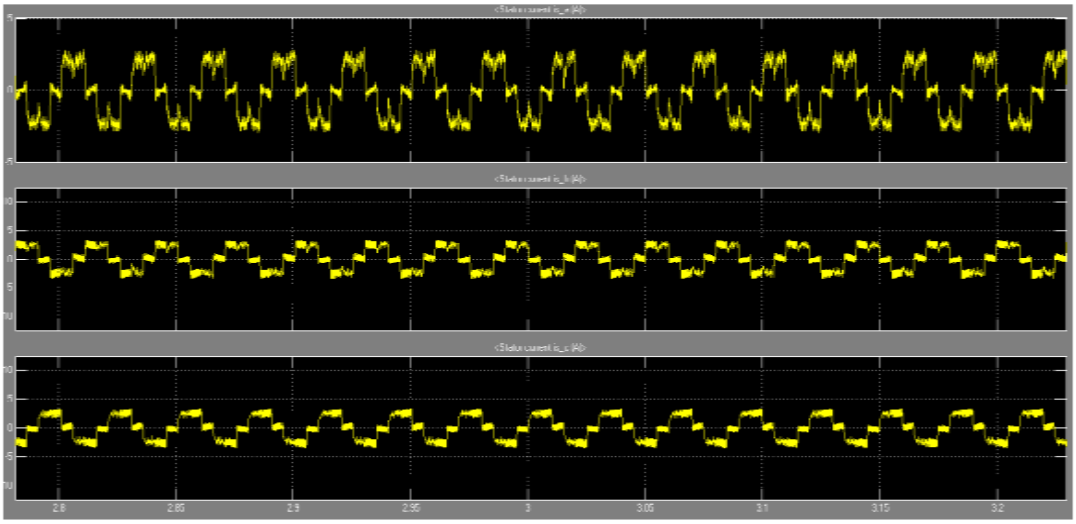

Figure 3. Phase current using fuzzy controller

F. MODELING OF FOUR SWITCH INVERTER FED PMBLDC WITH SENSOR LESS CONTROL

A BLDC motor can be controlled by sensor less control method. The implementation of a low cost , reduced parts BLDC motor is desired with high system reliability. But for reducing the manufacturing cost a feasible sensor less control method is developed by eliminating the position sensors . Also in harsh environments where these sensors cannot function reliably sensor less control is the only choice. Most of the sensorsless methods for a six-switch inverter BLDC motor drive are not directly applicable to the four-switch inverter The main reason is that in the four-switch topology, some methods detect less than six points, and other commutation instants must be interpolated via software. In this aspect too four switch topology minimizes the cost by using the ZCP of three voltages functions, that coincide to these six commutation instants rather than using complicated hardwares to carry out phase shift. Theoretical analysis and simulations on MATLAB/ SIMULINK were conducted to demonstrate the feasibility of the proposed sensor lessmethod . This paper presents a novel of sensor less method for four switch BLDC motordrive based on zero crossing points (ZCP) of stator line voltages of the BLDC motor.

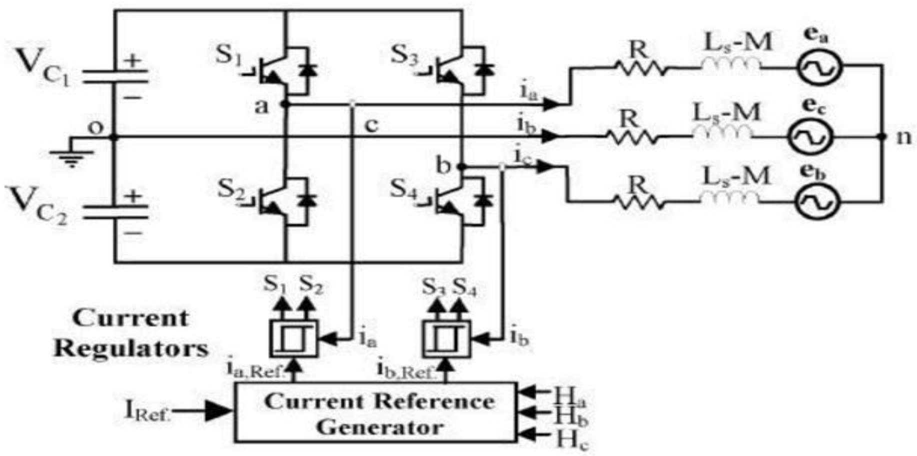

Figure 4.Current refrence Generator.,

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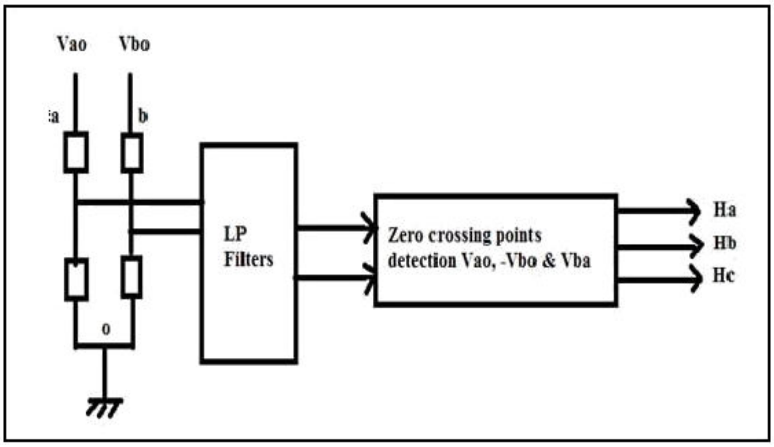
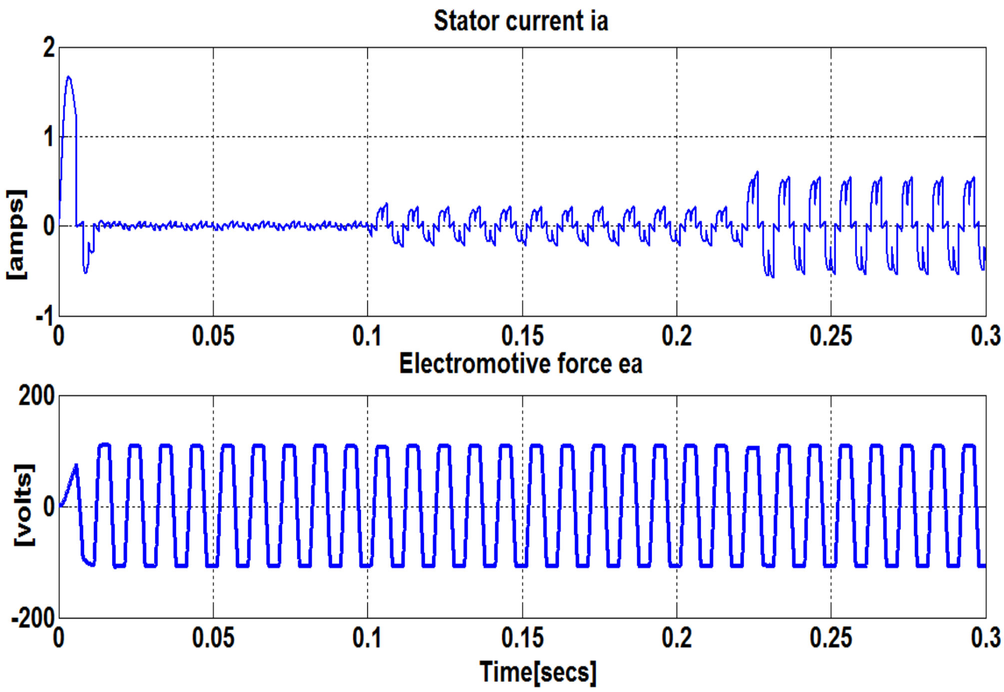


Figure 5. Positionsensing using line voltages.

Simulation results:



Graph-1 The stator current and back EMF waveforms of hybrid fuzzy PID controller of BLDC motor on speed of 2000 rpm

IV.CONCLUSION

In this proposed paper the modelling and simulation of the complete drive system is described in the paper. The performance of the Permanent magnet BLDC Motor drive with with the application of the fuzzy logic controller reference to both the steady state and the dynamic conditions is improved. To improve sensor less control performance, four-switch electronic commutation modes based proportional integral controller scheme is implemented. In 4-switch 3-phase inverter reduction of switches, cost control and saving of hall sensor were incorporated. The feasibility of the proposed sensor less control four-switch three phase inverter fed brushless DC motor drive is implemented, analyzed using MATLAB/SIMULINK, effective simulation results have been validated out successfully.

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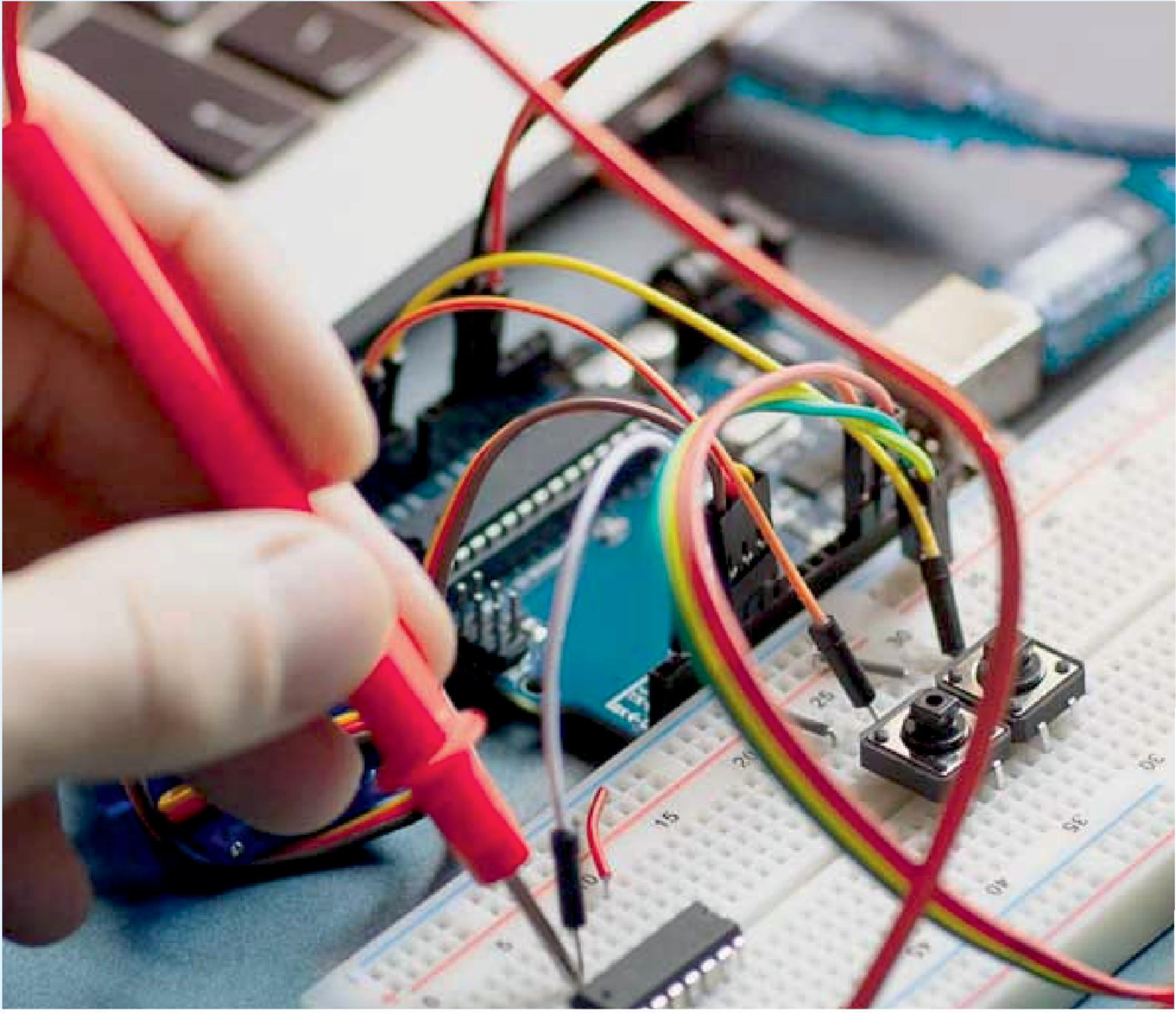

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