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SPEED AND FLUX CONTROL OF THE PM-BLDC MOTOR USING HYSTERESIS CONTROL TECHNIQUE

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ABSTRACT

Permanent Magnet Brushless DC (PM-BLDC) motors have become quite widespread and are utilized to serve for a variety of industrial purposes, because of their simple structure, high reliability and ease of control. Space Vectors theory is one of the most widely used methods which is implemented for controlling PM-BLDC. Supposing that each space vector refers to a unique arrangement of switch states, this theory calculates speed (or torque) error and stator flux error, compared to reference parameters. Consecutively, based on the aforementioned issues the most appropriate voltage vectors are attained to excite the stator phases. Ripples in speed and torque, are the main concerns, such methods try to deal with. In this paper, in addition to speed and flux errors, the speed variation slope is used as an auxiliary control parameter for a more precise speed control and decreasing speed ripples. The simulation results demonstrate a promising efficacy and accuracy of the proposed method.

Keywords: PM-BLDC motors, Space Vectors Theory, Speed Control.

INTRODUCTION

BLDC motor, as National Electrical Manufacturers Associations (NEMA) clearly defines, is "a rotating self synchronous machine with a permanent magnet rotor and with known rotor shaft position for electronic commutation". These motors mostly have concentrated windings on their stators which are fed by a power electronic converter. In recent years, regarding their specific advantages, PMBLDC- equipped variable speed drives, have found multifarious usages in industry. Of these advantages, simple structure, ease of control, high efficiency, high power density and large torque-to-inertia ratio, can be enumerated. Aeronautics, Electric Vehicles, Servo Drives, military and domestic usages are the main industrial area that make use of PM-BLDC motors. In literature, a variety of methods have been put into practice to control the speed and torque of PM-BLDC motors.

All of the proposed control methods have aimed to reach a ripple-free speed and torque besides flux control. Within the previous decades, conventional controllers such as P, PI and PID were mainly used for controlling PM-BLDC motors. Since such methods require real-time calculations and controllers with a high-speed response in order to track reference current, they have a perplexing implementation. A Brushless DC motor is an electric motor driven by an electrical input, which lacks any form commutator

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or slip ring. The motor requires some form of alternating current to turn, either from an AC supply, or an electronic circuit.

BLOCK DIAGRAM

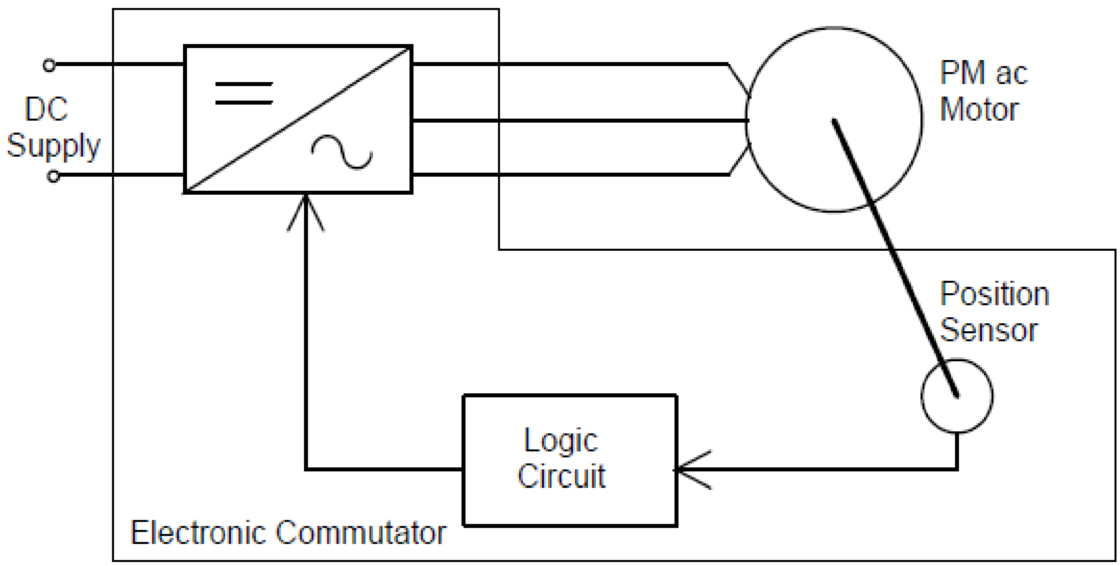


Fig 1 Block diagram of speed control of PM-BLDC motor

Brushless dc motor = Permanent magnet ac motor + Electronic commutator

In a brushless DC motor having a magnet and multiphase coils, a current is distributed from a DC voltage source to the multiphase coils according to a set of output signals of a position detector for detecting the relative position between the magnet and the multiphase coils. First and second sets of output transistors are used so as to distribute a current to the corresponding multiphase coils. A first distributor selectively activates the first output transistors corresponding to the output signals of the position detector so as to supply the multiphase coils with a current according to a command signal, and a second distributor also selectively activates the second output transistors corresponding to the output signals of the position detector. A second distributor has a voltage drop controller for detecting voltage drops across the first set of output transistors in each activated period and for controlling output currents of the second set of output transistors so as to maintain the voltage drops across the first set of output transistors in each activated period at a predetermined value regardless of the relative position between the magnet and the multiphase coils.

OBJECTIVE

The main objective of the implementing hysteresis controller in PM-BLDC motor is to reduce switching loss which occur due to conventional PWM techniques. The Hysteresis band PWM technique has been selected, since it has the potential to provide an improved method of deriving non-linear models which is complementary to conventional techniques. With this method, lower order harmonics can be eliminated or minimized along with its output voltage control. Current errors for the three phases are determined and a hysteresis block is employed for each phase. The outputs of HB-PWM controller, which are pulses, are given to inverter.This is to design and implement the hysteresis current control technique as a controller to the PMBLDC motor. To interface the MATLAB Simulink and to control the current that supply into the motor. Hysteresis controller is simple in implementation which reduces current error efficiently. The switches are controlled asynchronously. The current controllers are designed to operate independently. Speed ripples are reduced efficiently. Hysteresis current controller used in shunt active filter applications and also in silicon labs. It is Preferred for powering electric bikes. Permanent magnet motors are ideal for applications up to about 5KW.Used for traction applications from low power wheel chairs to some higher power automotive uses.

STRUCTURE

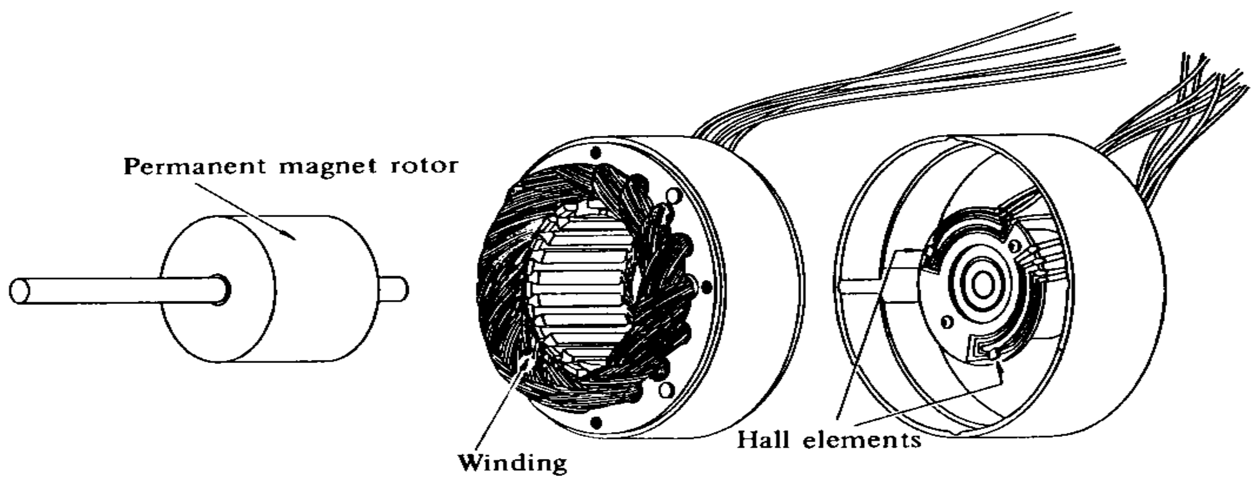
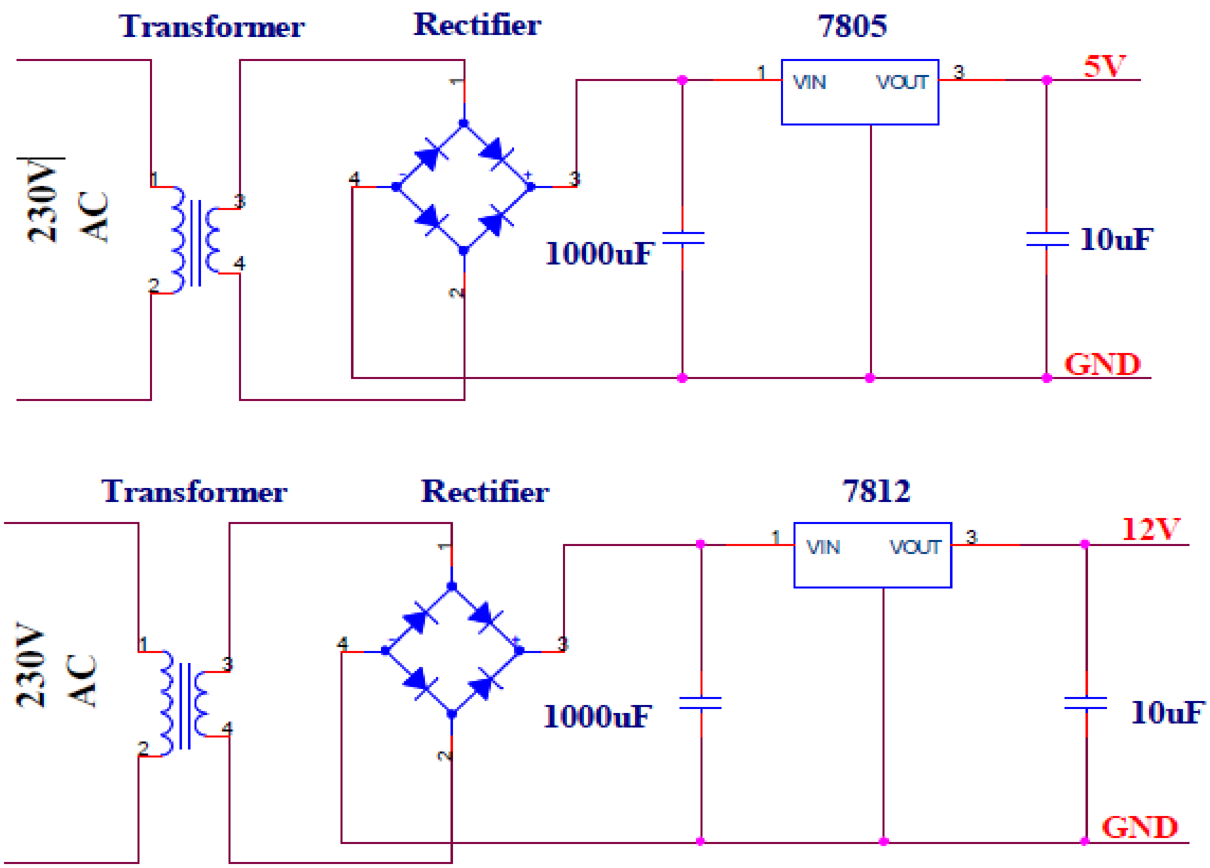


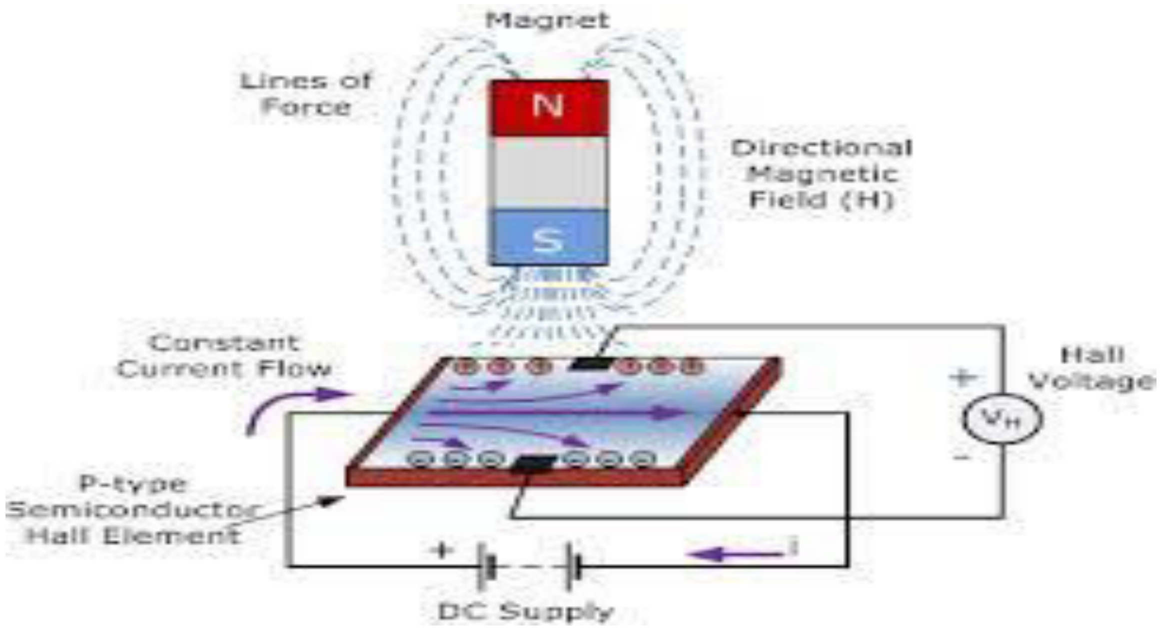
Fig 2 Disassembled view of a brushless dc motor

The construction of modern brushless motors is very similar to the ac motor, known as the permanent magnet synchronous motor. Fig. illustrates the structure of a typical three-phase brushless dc motor. The stator windings are similar to those in a polyphase ac motor, and the rotor is composed of one or more permanent magnets. Brushless dc motors are different from ac synchronous motors in that the former incorporates some means to detect the rotor position (or magnetic poles) to produce signals to control the electronic switches. The most common position/pole sensor is the Hall element, but some motors use optical sensors. Although it is said that brushless dc motors and conventional dc motors are similar in their static characteristics, they actually have remarkable differences in some aspects. When we compare both motors in terms of present-day technology, a discussion of their differences rather than their similarities can be more helpful in understanding their proper applications. Table 1 compares the advantages and disadvantages of these two types of motors. When we discuss the functions of electrical motors, we should not forget the significance of windings and commutation. Commutation refers to the process which converts the input direct current to alternating current and properly distributes it to each winding in the armature. In a conventional dc motor, commutation is undertaken by brushes and commutator; in contrast, in a brushless dc motor it is done by using semiconductor devices such as transistors.



HALL EFFECT ROTOR POSITION SENSOR

C.Nandhini, Prof.A.Ambika, et al., Inter. J. Int. Adv. & Res. In Engg. Comp., Vol.–04 (03) 2016 [85-97]



SINUSOIDAL BAND CURRENT CONTROLLER

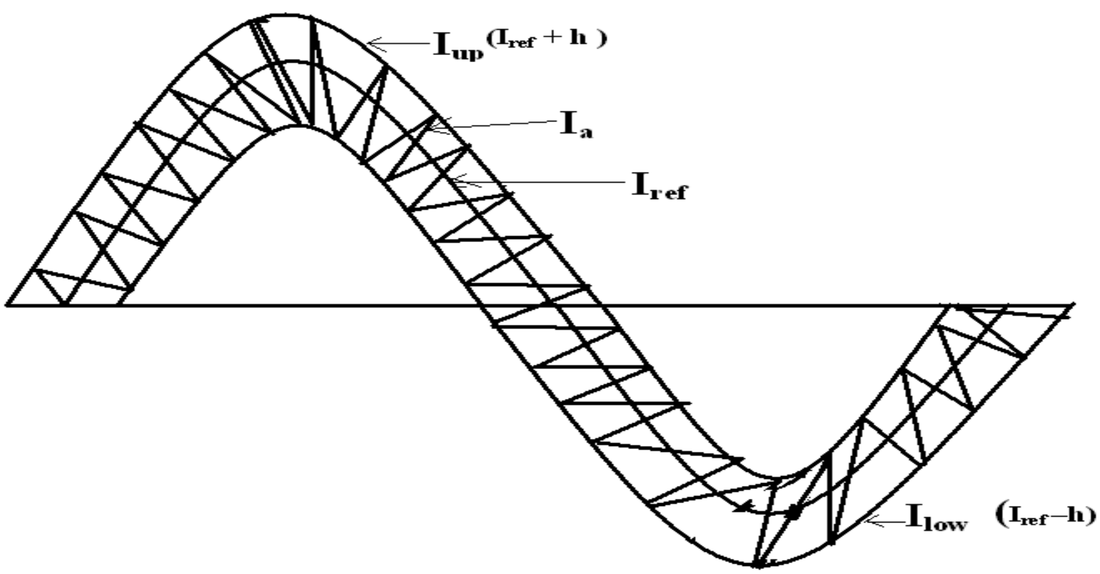


Fig.3 sinusoidal band current controller

The fixed band current controller gives good dynamic performance; but switching frequency is irregular and current ripple is large. In the case of sinusoidal band current controller the ripple can be varied with the current magnitude thereby reducing the current ripple content. In sinusoidal band as compared to fixed band current ripple content is less.

C.Nandhini, Prof.A.Ambika, et al., Inter. J. Int. Adv. & Res. In Engg. Comp., Vol.–04 (03) 2016 [85-97]

HYSTERESIS BAND CONTROL TECHNIQUE

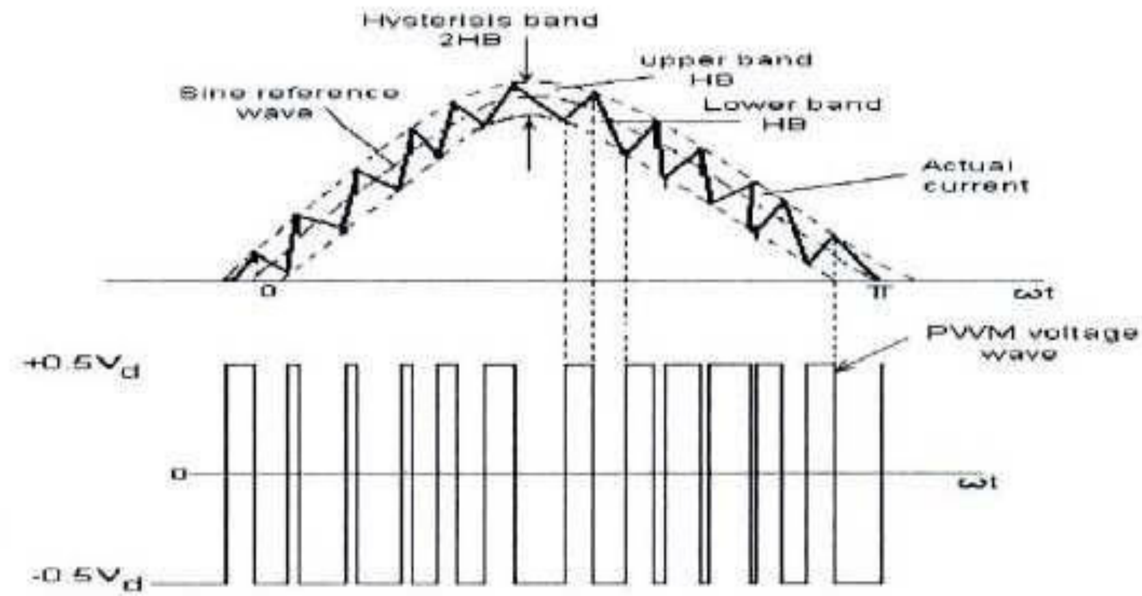


Fig.4 Hysteresis band control technique

EXPLANATION

The hysteresis-band current control method is used because of its simplicity in implementation. It derives the switching signals of the inverter power switches in a manner that reduces the current error. The switches are controlled asynchronously to ramp the current through the inductor up and down so that it follows the reference. When the current through the inductor exceeds the upper hysteresis limit, a negative voltage is applied by the inverter to the inductor. This causes the current through the inductor to decrease. Once the current reaches the lower hysteresis limit, a positive voltage is applied by the inverter through the inductor and this causes the current to increase and the cycle repeats. Today DTC is recognized as a high performance control method for AC machines, allowing for fast torque control. In addition, DTC is very interesting and attractive from a conceptual point of view, because it integrates directly and clearly the power circuit of the inverter and the gate drive pulses generation with the behaviour of torque and flux in the machine. Two hysteresis comparators and the position of the motor flux were used to generate directly the gate pulses for the power transistors of the inverter. This field oriented control method was compared with direct torque control and concluded that both control methods, although being conceptually different, have very similar features in terms of structure and performance.

BLOCK DIAGRAM

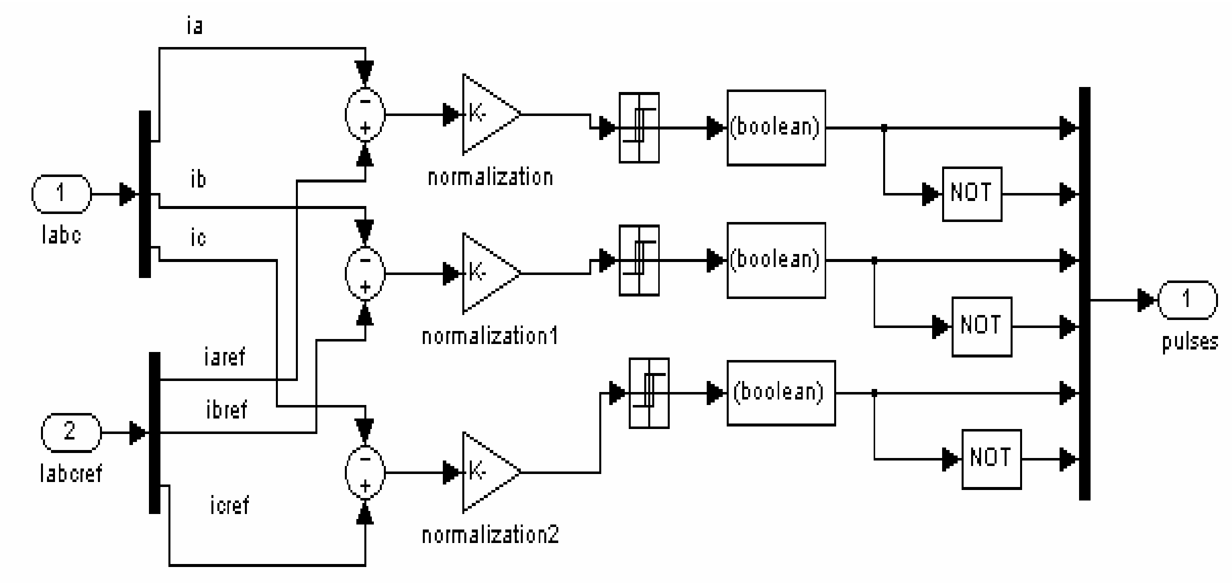


Fig.5 block diagram of hysteresis comparator

The Hysteresis band PWM technique has been selected, since it has the potential to provide an improved method of deriving non-linear models which is complementary to conventional techniques. With this method, lower order harmonics can be eliminated or minimized along with its output voltage control. Current errors for the three phases are determined and a hysteresis block is employed for each phase. The outputs of HB-PWM controller, which are pulses, are given to inverter. The hysteresis-band current control method is used because of its simplicity in implementation. It derives the switching signals of the inverter power switches in a manner that reduces the current error. The switches are controlled asynchronously to ramp the current through the inductor up and down so that it follows the reference. When the current through the inductor exceeds the upper hysteresis limit, a negative voltage is applied by the inverter to the inductor. This causes the current through the inductor to decrease. Once the current reaches the lower hysteresis limit, a positive voltage is applied by the inverter through the inductor and this causes the current to increase and the cycle repeats.

CIRCUIT DIAGRAM

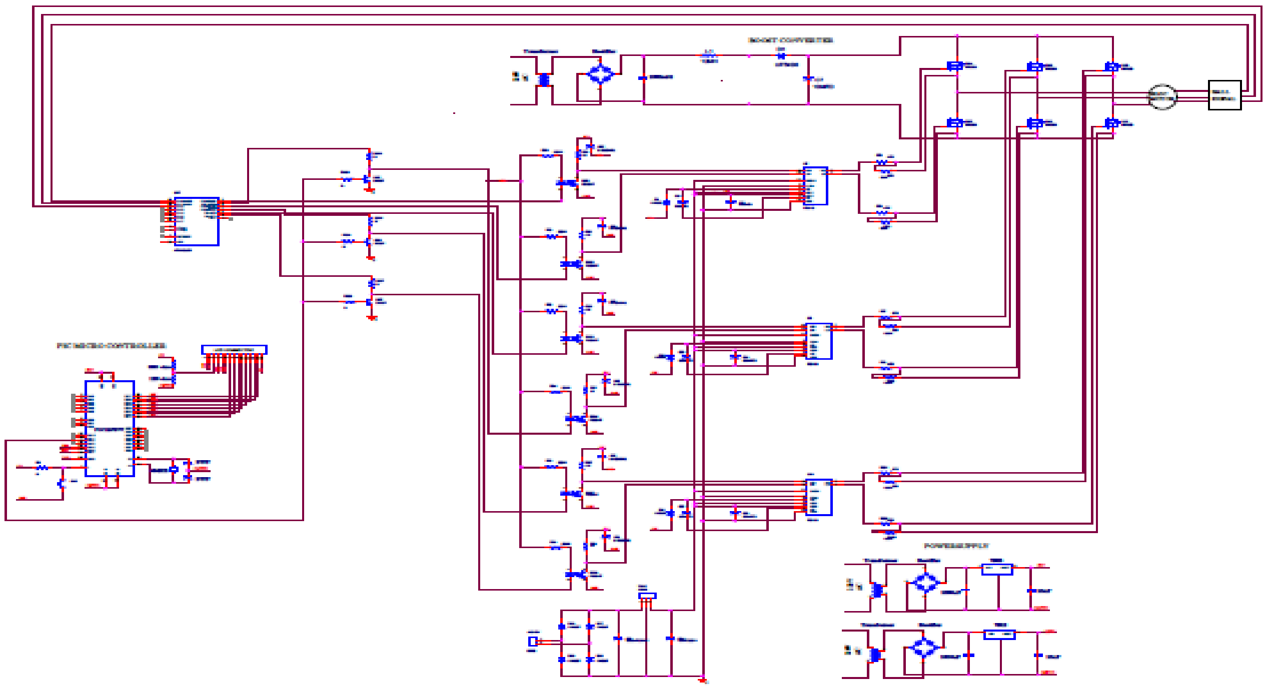


Fig.6 Circuit diagram of speed control of BLDC motor

MODELLING AND SIMULATION OF PROPOSED SYSTEM

HALL SENSOR

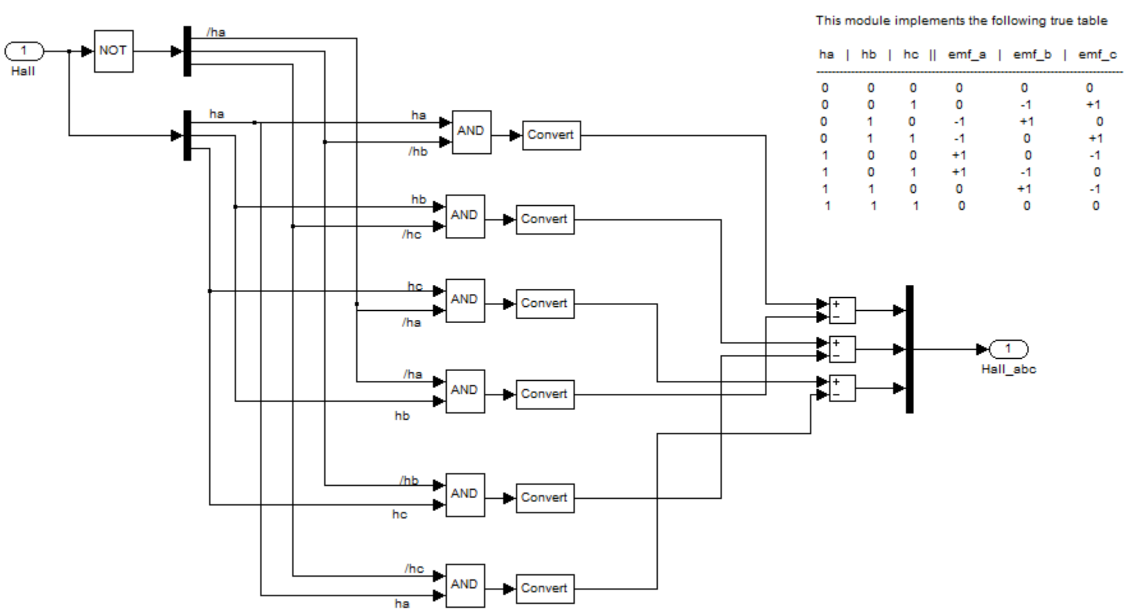


Fig.7 Simulation circuit of hall sensor

Hall effect rotor position sensor is used to detect the position of the rotor and sends signals to the controller to generate pulses which is used to gate the inverter circuit.Here the hall voltage for three phases are generated and the voltage of any two phases is given to AND gate which makes its logic function. Finally hall emf for three phases are generated as shown in truth table. When a beam of charged particles passes through a magnetic field, forces act on the particles and the beam isdeflected from a straight path. The flow of electronsthrough a conductor is known as a beam of charged carriers.When a conductor is placed in a magnetic field perpendicular to the direction of the electrons, they will be deflected from a straight path. As a consequence, one plane of the conductor will become negatively charged and the opposite side will become positively charged. The voltage between these planes is called Hall voltage.

PULSE WIDTH MODULATION GENERATION

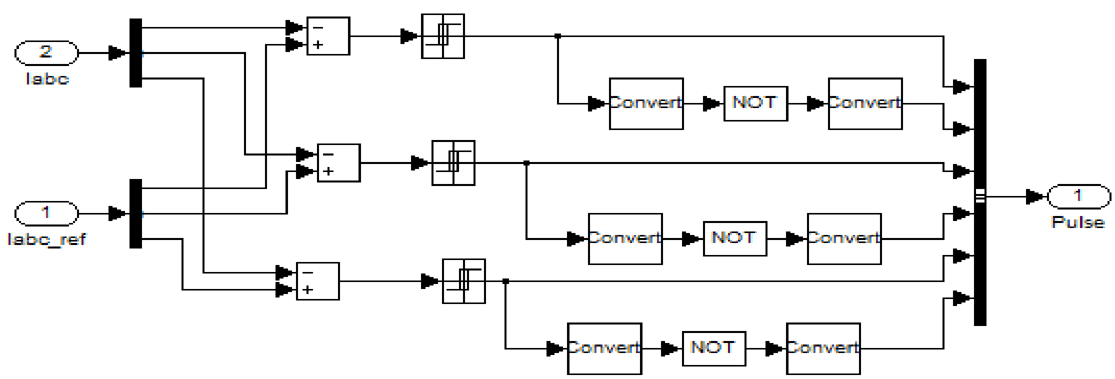


Fig.8 Simulation of PWM generation

In the pulse width generation technique phase current and reference current are compared in the hysteresis comparator and pulses are generated. Here any two of three phase and reference currents are compared and error signal is amplified and pulses are given as logic 1 to gate the semiconductor devices of the inverter circuit and logic 0 to off the semiconductor devices. The control circuit generates sine reference current wave of desired magnitude and frequency and it is compared with actual phase current wave. As the current exceeds a prescribed hysteresis band, the upper switch in the half-bridge is turned off and the lower switch is turned on. As a result the output voltage transitions from +0.5Vd to -0.5Vd, and the current starts to decay. As the current crosses the lower band limit, the lower switch is turned off and the upper switch is turned on. The actual current wave is thus forced to track the sine reference wave within the hysteresis band by back- and-forth switching of the upper and lower switches. The inverter then essentially becomes a current source with peak to peak current ripple, which is controlled within the hysteresis band irrespective of Vd fluctuation. The peak-to peak current ripple and the switching frequency are related to the width of the hysteresis band. The inputs to the HBPWM controller are three phase current errors and the outputs are the switching patterns to the PWM inverter.

SIMULATION OF SPEED AND FLUX CONTROL OF PM-BLDC MOTOR USING HYSTERESIS CONTROLLER

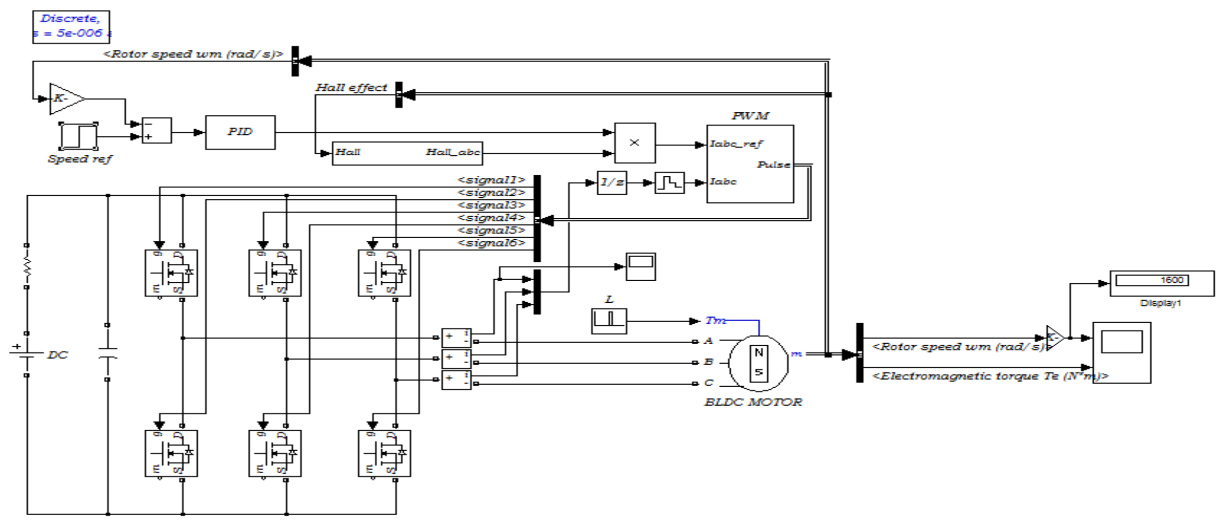


Fig.9 Simulation of PM-BLDC motor using hysteresis controller

In the speed and flux control of PM-BLDC motor ac supply is converted to dc using rectifier and stored in the battery bank.It is then converted to ac using three phase voltage source inverter and speed of rotor and position of BLDC motor is sensed using hall effect rotor position sensor. The rotor speed is compared with reference speed and speed error is rectified using PID controller. The hysteresis-band current control method is used because of its simplicity in implementation.It derives the switching signals of the inverter power switches in a manner that reduces the current error. The switches are controlled asynchronously to ramp the current through the inductor up and down so that it follows the reference. When the current through the inductor exceeds the upper hysteresis limit, a negative voltage is applied by the inverter to the inductor. This causes the current through the inductor to decrease. Once the current reaches the lower hysteresis limit, a positive voltage is applied by the inverter through the inductor and this causes the current to increase and the cycle repeats. The Hysteresis band PWM technique has been selected, since it has the potential to provide an improved method of deriving non-linear models which is complementary to conventional techniques With this method, lower order harmonics can be eliminated or minimized along with its output voltage control. Current errors for the three phases are determined and a hysteresis block is employed for each phase. The outputs of HB-PWM controller, which are pulses, are given to inverter.

SIMULATION RESULTS OF PROPOSED SYSTEM

SPEED CURVE

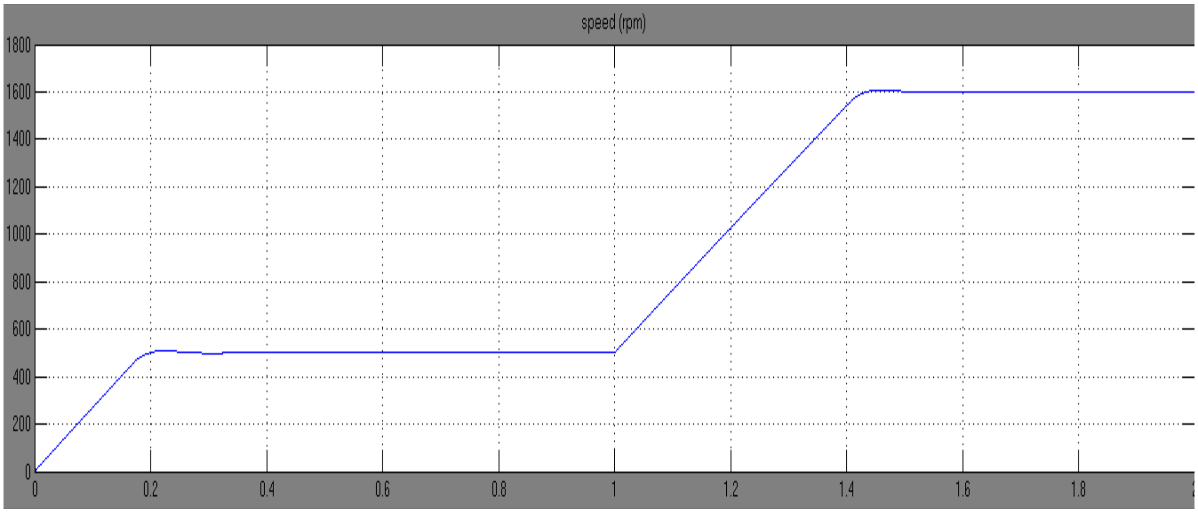


Fig.10 Speed curve

In the speed control of PM-BLDC motor using hysteresis controller speed is controlled in the wide range from 500 rpm to 2000 rpm. Hysteresis controller is used in order to reduce the current error and also to reduce the switching losses. This hysteresis band PWM technique is advantageous compared to the other PWM techniques because there is no conduction losses. Here the current is made to ramp between hysteresis upper band and lower band limit. Hence the speed fluctuations and torque ripples are reduced.

ELECTROMAGNETIC TORQUE CURVE

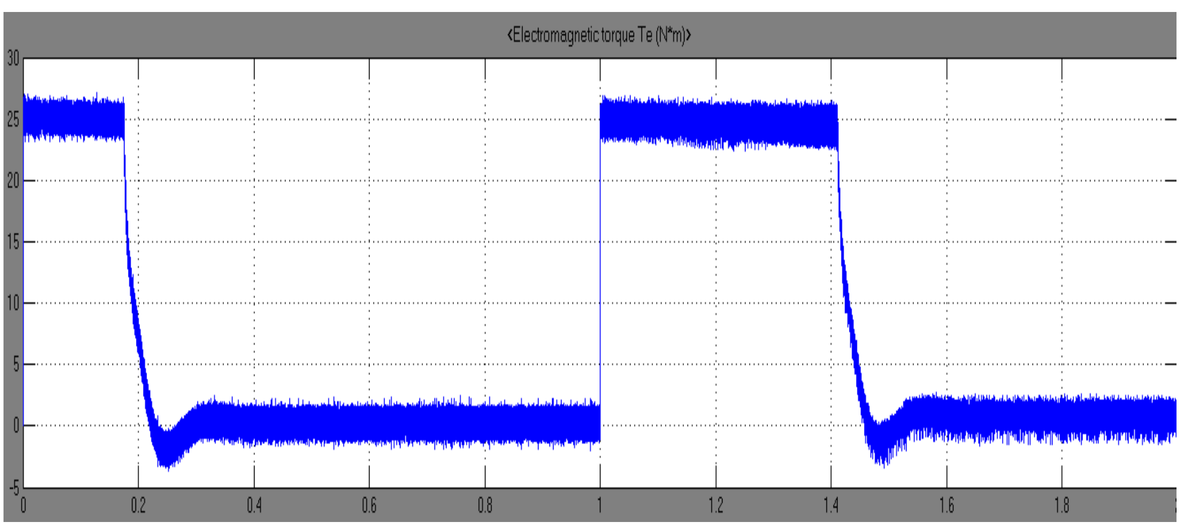


Fig.11 Electromagnetic torque curve

It is the torque developed inside an electric motor. Current passed through through a coil of wire(winding inside the motor) creates a magnetic field. In a properly designed motor, this field will be attracted to, or repelled from, another magnetic field also created in the motor. The attraction or repulsion is a force, and in a motor the force is directed to cause rotary motion.This is because the windings of the rotating part of the motor will create fields in opposition to the windings in the stationary part of the motor-similar to the way north and south poles on a bar magnet attract each other while 2 norths or 2 souths repel each other.

CONCLUSION

In case of space vector modulation owing to the usage of two phase and three phase conduction mode switching states are high which may lead to switching losses. Thus hysteresis controller is designed to reduce the current error to operate PM-BLDC motor under high efficiency. The speed and torque ripples are reduced than in that of the conventional system. Switching loss is also reduced as compared to space vector modulation technique. Finally the output is closely related to fundamental frequency and THD (total harmonic distortion) is also reduced. In this paper an improved method is proposed to control PM-BLDC motors, which makes use of hysteresis comparator which reduces the speed ripple problem. In addition to the parameters used in similar speed control methods, such as rotor speed and stator flux, the slope of speed variations is used as an auxiliary control parameter to perform a more accurate speed control in the adjacency of reference speed and reduce speed ripples. The hysteresis modulator is modified to reduce the switching losses by applying variable frequency; to make the generated current swing symmetrically around the reference signal with minimum possible ripple, and to adapt the hysteresis band for any current. The generated current can be forced to symmetrically swing around the reference signal by making constant ripple among the whole cycle. The ripple of the generated current is dependent on different factors such as: instantaneous supply voltage, dc bus voltage, coupling inductor, and the switching time. The only controlled variable from these factors is the switching time. The switching time can be controlled by changing the hysteresis band.

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