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Simulation Modeling of Inverter Controlled BLDC Drive using Four Switch

Mr. MOHANKUMAR R

PG – Scholar in Power Electronics and Drives

Department of Electrical and Electronics Engineering

P.S.V. College of Engineering and Technology

Krishnagiri – 635108, Tamilnadu ,India

Professor. K.GOPINATH, M.E

Assistant professor

Department of Electrical and Electronics Engineering

P.S.V. College of Engineering and Technology

Krishnagiri – 635108, Tamilnadu ,India

Mobile no:9698131414

ABSTRACT

The main purpose of this paper is to describe the four-switch brushless dc (BLDC) motor drive for various applications. For effective utilization of the developed system, a novel direct current controlled pulse width modulation scheme is designed and implemented to produce the

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desired dynamic and static speed–torque characteristics. Also, the feasibility of the four-switch converter.

Key words: purpose, motor drive, effective utilization, novel direct, implemented

Chapter -I

1. INTRODUCTION

In recent years, Brushless DC (BLDC) motor drives are increasingly popular in industrial applications due to rapid progress of technologies in power electronics and growing demand for energy saving. A BLDC motor is a type of permanent magnet synchronous motor that uses position decoders and an inverter to control the armature current. Instead of using a mechanical commutator as in the conventional dc motor, the BLDC employs electronic commutation without the mechanical commutators and brushes which makes it a virtually maintenance free motor know as “Brushless Direct Current Motor”.

The operating characteristics of BLDC motor resemble that of conventional commutated dc permanent magnet motor. Hence many problems associated with brushes such as radio-frequency interference and sparking which are the potential sources of ignition inflammable atmosphere are eliminated. A motion A motion system based on the Direct Current (DC) provides a good, simple and efficient solution to satisfy the requirements of a variable speed drive.

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Although dc motors possess good control characteristics and ruggedness, their performance and applications in wider area inhibited due to sparking and commutation problem. Squirrel cage induction motor does not possess the above mentioned problems, but they have their own limitations such as low power factor and non-linear speed torque characteristics. With the advancement of technology and development of modern control techniques, the Permanent.Magnet Brushless DC (PMBLDC) motor is able to overcome the limitations mentioned above and satisfy the requirements of a variable speed drive.

The concept of the BLDC motor is actually very old, going back to 1962 when T.G. Wilson and P.H. Trickey made a DC machine with solid state commutation. It is highly suitable for special applications such as tape and disk drives for computers, robotics, positioning systems and aircraft where high torque and fastness of response are very much essential. In addition, it is more suitable in applications where wear is intolerable due to low humidity. Unfortunately, the technology to make such a motor practical for industrial use over 5 H.P simply did not exist until a number of years later.

With the advent of powerful and permanent magnet materials and high power, high voltage transistors in the early to mid 80's the ability to make such a motor practically became a reality. The first large BLDC motor (50 H.P or more) was designed by Robert E. Lordo at POWERTEC Industrial corporation in the late 1980s. Simple construction is a prime feature of this motor. BLDC motor eliminates brushes, commutators and hence the excellent overall performance of BLDC motor makes it an efficient competitor for AC drives.

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It has been widely used in drive systems and servo control because of its fast response, lower Electromagnetic Interference (EMI), high power density, high efficiency, high reliability, quiet operation and maintenance free. The motor consisting of permanent magnet rotor and distributed stator windings are wound such that electromotive force is trapezoidal. They have better speed torque characteristics and low inertia, which improves their dynamic performance when compared to a dc MOTOR.

BLDC motor is usually supplied by a hard-switching Pulse Width Modulation (PWM) inverter, which normally has relatively low efficiency since the power losses in switching devices are high. The high dv/dt and di/dt will result in severe EMI and rigorous problems with the reverse recovery of the freewheeling diodes, especially in high switching frequency.

As the switching frequency of the hard-switching is not very high when the switching frequency is within audio spectrum, it may produce severe acoustic noise. Furthermore, there is “turning off current spike” for inductive load or “turning on voltage spike” for capacitive load with a hard-switching inverter, which can produce excessive localized hot spots and damage power semiconductor switches. In order to solve these problems, many soft-switching inverters have been designed in the past but they have their own limitations.

To overcome all these problems, the soft-switching inverter using transformer is used, which can generate dc link voltage notches during chopping and minimize the drawbacks of existing soft-switching. Hence all switches work in zero-voltage switching condition.

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In this thesis, the performance of the hybrid intelligent controllers are compared with conventional PI controller, because conventional PI controller requires exact mathematical model of the system and are very sensitive to parameter variations. Therefore, the use of conventional PI controller does not meet the requirements for the robust performance.

In recent years, there has been an increasing interest in the development of efficient control strategies to improve dynamic behavior of the BLDC motor by using Fuzzy Logic Controller (FLC), Hybrid Fuzzy-PI, Genetic Algorithm based PI (GA-PI), and Adaptive Neuro-Fuzzy Inference System (ANFIS) controller.

Both the simulation and experimental results show that the ANFIS controller based soft-switching inverter is designed for BLDC motor drive systems which is easy to implement in industries and it has the advantages of low switching power loss, low inductor power loss, low dc link voltage ripple, small device voltage stress, low switching noise and simple control scheme. Moreover the system provides low torque ripples, high starting torque, better transient response with negligible overshoot, smaller settling time and rise time.

1.2 OBJECTIVE OF THE THESIS BLDC MOTOR

Objective of the thesis BLDC motor is usually supplied by a hard-switching PWM inverter, which normally has relatively low efficiency since the power losses across the switching devices are high. The high dv/dt and di/dt will result in severe EMI and rigorous problem with the reverse recovery of the freewheeling diodes, especially in high switching

frequency. As the switching frequency is within audio spectrum, it may produce severe acoustic noise

. In order to solve these problems, many soft-switching inverters have been designed in the past. Unfortunately, high device voltage stress, large dc link voltage ripples, complex control scheme and so on are noticed in the existing soft-switching inverters.

The objective of the work is to minimize the switching power loss, inductor power loss, dc link voltage ripple, device voltage stress, switching noise and complex control scheme. These variables are calculated and shown in appropriate places

CHAPTER 2

2.1 EXISTING SYSTEM

There are several existing procedures for power factor correction in modern days.drawbacks of transfer function model and merits of state space model are discussed. The construction and working principle of BLDC motor and determination of motor equivalent model parameters are discussed. The state space model of the BLDC motor is derived. Using the state space model of BLDC motor with hard-switching inverter together with conventional PI controller, the performance characteristics such as three phase back EMFs, three phase currents, rotor angle and rotor speed are obtained using MATLAB simulation software. This study is useful for the comparison purpose when intelligent controllers with a new proposed soft-switching inverter are used in the subsequent chapters. From literature survey, it is well

known that the performance of the BLDC motor with conventional PI controller and hard-switching inverter has many drawbacks.

2.1.1STATIC CAPACITOR BANK

Capacitors causes leading power factor as it shifts current ahead of the voltage. So to correct lagging power factor, it is a convenient method for which this method is practiced worldwide vastly. Though it has some limitations like the inability to absorb harmonics and doesn't provide step-less correction, it is a popular choice for PFC for its low cost of installation and maintenance.

CHAPTER 3

3.1 PROPOSED SYSTEM

The proposed system consist of automated control system of load management here purpose of controlling the load is, not to exceed the contracted maximum load limit. The BLDC motor is a type of permanent magnet synchronous motor that uses position decoders and an inverter to control the armature voltage supplied to the motor.

It employs electronic commutation without the mechanical commutators and brushes. The operating characteristics of BLDC motor resemble that of conventional commutated dc permanent magnet motor.

Though dc motors possess good control characteristics and ruggedness, they produce sparking and commutation problem. Induction motor has low power factor and non-linear

speed torque characteristics. Hence the PMBLDC motor offers viable solution to overcome the limitations of dc and induction motor and satisfy the requirements of a variable speed drive using recent control techniques.

BLDC motor eliminates brushes, commutators and hence provides excellent overall performance. It is an efficient competitor for AC drives. It has many advantages such as fast response, lower electromagnetic interference, high power density, high efficiency, high reliability, quiet operation and maintenance free.

The detailed literature survey reveals that, in the past analysis of BLDC motor characteristics was done using transfer function model. However, recent control techniques which give improved performance uses state space model. It is therefore necessary that the BLDC motor is represented in state space model.

It is also learned, that inverters are employed to control the armature voltage of the BLDC motor. In the past, hard-switching inverters were invariably used. However they have several drawbacks. Some authors have attempted to design soft-switching inverters. In these inverters, more number of switching devices are used.

Hence, high device voltage stress, large dc link voltage ripples with complex control scheme are observed and they are to be eliminated for the proper design of the inverter with the use of appropriate controllers.

Performance evaluation of BLDC motor is done based on power loss across switching devices, efficiency, inductor power loss, switching noise, control scheme, dc link voltage

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ripples, torque ripples and voltage stress across switches. The drawbacks with the lack of these parameters are noticed in the literature survey. In this thesis, an attempt has been made to rectify the above drawbacks using soft-switching inverter with intelligent controllers. The next chapter explains in details about the state space modeling of BLDC motor with MATLAB simulation software.

3.2 BLOCK DIAGRAM

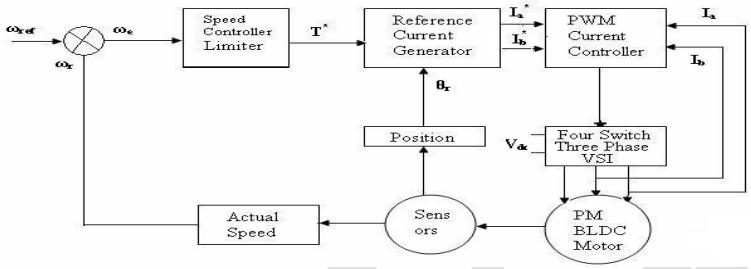

Fig 3.1 Block diagram of proposed PI-Speed Controller system

3.3 CIRCUIT DIAGRAM

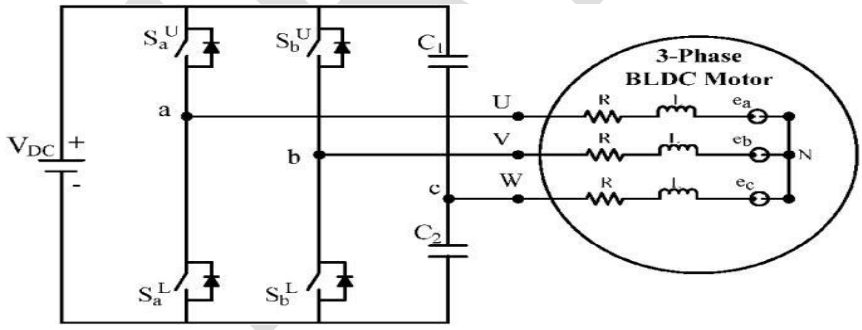

Fig 3.2 Circuit diagram of PI speed controller.

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3.1FOUR-SWITCH CONVERTER

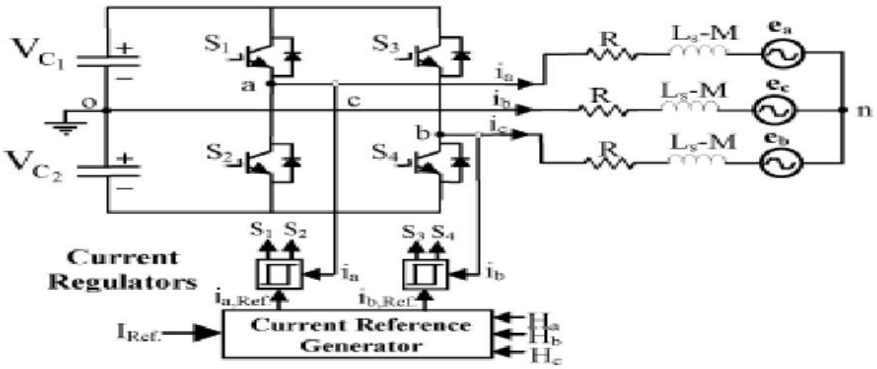

Fig 3.3Proposed four-switch converter topology for three-phase BLDC motor.

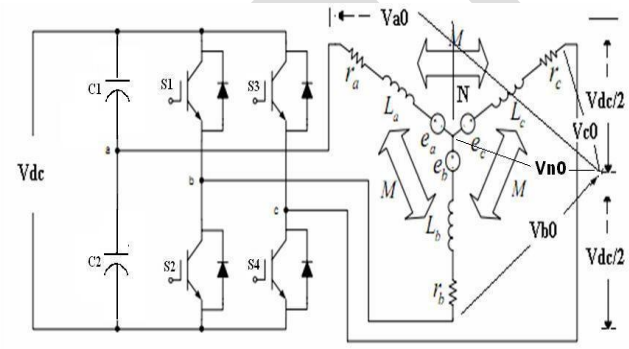

Fig.3.4 Inverter circuit with PMBLDCM drive

3.4 TABLE

MODES	ACTIVE PHASES	SILENT PHASES	SWITCHING DEVICES

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Mode 1	Phase B and C	Phase A	S4
Mode 2	Phase A and B	Phase C	S1 and S4
Mode 3	Phase A and C	Phase B	S1
Mode 4	Phase B and C	Phase A	S3
Mode 5	Phase A and B	Phase C	S2 and S3
Mode 6	Phase A and C	Phase B	S2

Table 3.5 Switching Sequence of Four switch BLDC motor

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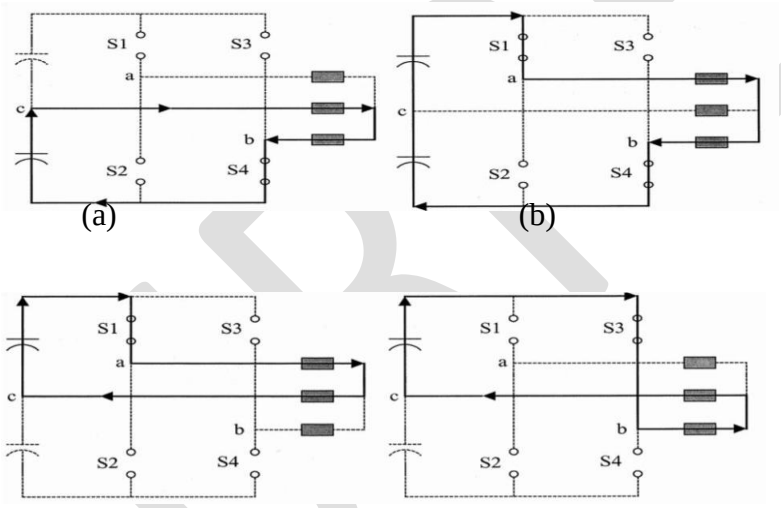
Terminal voltages of a BLDC motor in the fourswitch inverter with respect to the mid-point of the dc bus are as follows:

$$V_{ao} = Ri_a + L\frac{di_a}{} + e_a + V_{no}$$

As s hown in Table II, the two-phase currents need to be directly controlled using the hysteresis current control method by four switches. Hence, it is called the direct current controlled pwm scheme. Based on the direct current controlled pwm, implementation of the switching sequence and current flow are depicted in Fig. 3.5

3.5 SWITCHING SEQUENCE



(a) (b)

(c) (d)

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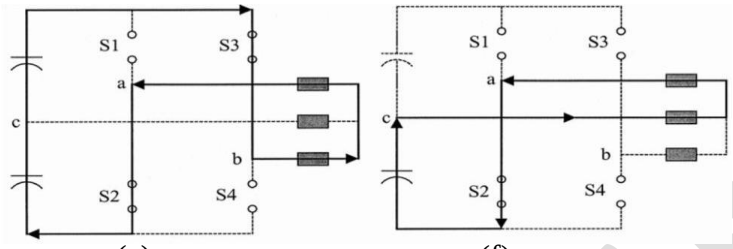

(e) (f)

Fig. 3.6. Implementation of the direct current controlled pwm strategy. (a) Mode I (S4). (b) Mode II (S1 and S4). (c) Mode III (S1). (d) Mode IV (S3). (e) Mode V (S3 and S2). (f) Mode VI (S2).The bold line is the current reference value, which is obtained from the torque and speed control loop to achieve the reference torque. The switching frequency and torque ripple are the main considerations for setting the upper and lower limits. It means that a smaller band causes higher switching frequency, but lower torque ripple.

Using mode II and mode III, the current regulation can be explained as follows: In mode II,Ia and Ib currents (Ia>0 ,Ib<0) flow and Ic=0. Therefore,mode II is divided into two cases, such as dia/dt>0,dib/dt<0 and dia/dt<0,dib/dt>0.In this mode, as shown in Fig. 6(b), switches S1and S5 are used.

Until Ia(Ib) reaches the upper (lower) limit, S1 and S4 are turned on for supplying dc-link energy to increase the current.When the current reaches to the upper limit, S1and S4 are turned off to decrease the current through the anti-parallel diodes D2 and D3.

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At that time, the reverse bias (negative dc-link voltage) is applied to the phases, resulting in decreasing the current. On the other hand, in mode III, only one current (Ia) can be controllable.

It means that only switch S1 can be used as shown in Fig.However, the same principle as used for mode II is applied to mode III.When Ia increases,S1 is turned on and other case S1 is turned off.

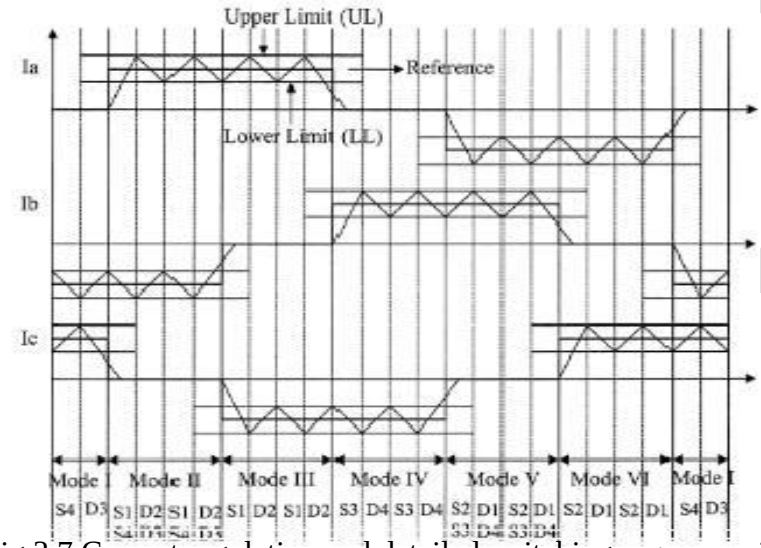

Fig.3.7 Current regulation and detailed switching sequences.in equilibrium.

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CHAPTER 4

CONCLUSION

The simulation model of the BLDC motor derive system with PI control based four switch three phase inverter on MATLAB/Simulink platform is presented. The performance of the developed algorithm based speed controller of the derive has revealed that the algorithm devises the behavior of the PMBLDC motor derive system work satisfactory. And also in this paper, the four switch inverter topology is studied to provide a possibility for the realization of low cost and high performance three phase BLDC motor derive system.

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