Performance & Analysis of Four Switch Three Phase Inverter Control for BLDC Motor using MATLAB – A Review

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Abstract—The main objective of this paper is to describe a low cost four-switch brushless dc (BLDC) motor drive for commercial applications. Speed control of three phase BLDC motor using four switch inverter is proposed to simplify the structure of the conventional six switch inverter. For effective utilization of the developed system, a novel direct current controlled PWM Scheme is designed and implemented to produce the desired dynamic and static speed–torque characteristics. PI controller is used by the outer loop to develop the performance of speed control. This paper gives a brief review of operational principle of the four-switch BLDC motor drive and the developed control scheme is theoretically analyzed and the performance is demonstrated by both simulation and experimental results in MATLAB.

Keywords: BLDC motor, Four-switch three phase inverter

I. INTRODUCTION

The adjustable-speed drive is preferred over a fixed speed motor due to energy saving, velocity or position control and amelioration of transients. The purpose of a motor speed controller is to take a signal representing the demanded speed and to drive the motor at that speed. [10] Brushless DC motors are mostly preferred because they offer several advantages, including long lifetime, reduced noise and good weight/size to power ratio. Brushless DC motors are used in a growing number of applications such as computer hard drives, CD/DVD players and PC cooling fans. Low speed, low power brushless DC motors are used in direct- drive turntables for analog audio records. High power BLDC motors are found in electric vehicles, hybrid vehicles and Some industrial machinery. The cost reduction of variable-speed drives is accomplished by two approaches. One is the topological approach and the other is the control approach. From a topology point of view, minimum number of switches is required for the converter circuit. In the control approach, algorithms are designed and implemented in conjunction with a reduced component converter to produce the desired speed–torque characteristics. As a result, many different converter topologies have been developed and various PWM control strategies have been proposed to enhance the performance of the system. [11] 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 is inherently 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 this study, the nonlinear simulation model of the BLDC motors drive system with proportional-integral (PI) control based on MATLAB/Simulink platform is presented.

II. DESCRIPTION OF REVIEW WORK CARRIED OUT

R. G. Shriwastava et al,[1] Studied Permanent Magnet Synchronous Motor (PMSM's), operating principle, uses, types, many applications and required rapid torque response and high–performance operation.

Pragasan Pillay et al,[2] had presented the dynamic models and equivalent circuits of two PM machines. It has shown that although the PMSM and BDCM are similar in construction, their modeling takes different forms. The *d*, *q* model of the wound rotor SM is easily adapted to the PMSM while an *abc* phase variable model is necessary for the BDCM if a detailed study of its behavior is needed.

G.Prasad et al,[3] had presented a model of three phase star connected brushless dc motor considering the

behavior of motor during commutation, comparative study is presented between sinusoidal and trapezoidal models of back-EMF in MATLAB which is very useful in studying the drive system before taking of the dedicated controller design.

R.Shanmugasundram et al,[4] presented a compact, economical high-speed driver and converter circuits and a pulse width modulation (PWM) control strategy implemented in a versatile Aduc812 micro controller for achieving better performance with low cost, compact BLDC drive using a versatile Aduc812 microcontroller is designed, implemented and tested. Also implemented several protective functions like over current protection, over voltage, and thermal protection of BLDC motor.

Bikram Das et al,[5] has studied a comparative study of CSI fed BLDC motor using Boost and Buck Converter Both the strategy significantly reduces the switching loss and cost thereby increasing the speed and efficiency of the BLDC motor drive system. The study is verified with the simulation results.

Vinod kumar Singh Patel et al,[6] has described a simpler way to control the speed of PM BLDC motor using pwm control method. The performance of the PM BLDC system is simulated and speed is regulated by PI controller. In order to highlight the effectiveness of the speed control method used which proposed suppresses torque oscillations and speed oscillations are minimized using closed loop system. Closed loop controlled VSI fed PMBLDC motor using pwm control is modeled and simulated in MATLAB.

Purna Chandra Rao et al,[7] has studied PID controller is applied for closed loop speed control under various loading conditions. The performance evaluation results shown that this modeling is very useful in studying the high performance drive before taking up the dedicated controller design concept for evaluation of dynamic performance of the motor also they presented a mathematical model of BLDC motor and show the values of various technical parameters using MATLAB/SIMULINK and simulation is carried out for 120 degree mode of operation.

Jibin M Varghese et al, [8] had presented the comprehensive study on the controllability and generated torque ripple of phase commutation in Four Switch Three Phase Inverter (FSTPI) Brushless DC (BLDC) motor drive which is suitable for low cost application. The algorithm is easy to implement on the microcontroller, and the cost of whole system is lowered because of reduced number of switches and current sensors. The proposed strategy shows good self adapted track ability also the structure of the drive is simplified. The simulation model of the BLDC motor drive system with single neuron PI controller based speed control and four switch three phase inverter on MATLAB/Simulink platform is presented.

J.Karthikeyan et al, [9] have presented a simple current controlled modulation technique for brushless dc motors. This current controlled technique is based on the generation of quasi- square wave currents using only one controller for the three phases. It uses a triangular carrier for the power transistors which is simpler and more accurate than any other options due to its advantages The stator currents are completely characterized by their maximum amplitude, the three phases are controlled with the same dc component, and then the phase currents are kept at exactly the same magnitude, the dc link current measurement is not required, phase currents are kept balanced and phase over currents are eliminated etc. This control Strategy had compared with conventional techniques to show the excellent characteristic of this modulation technique in MATLAB.

Dr. R.Seyezhai, [12] has presented a comparison between symmetric and asymmetric MLI using variable frequency carrier based pulse width modulation technique. They presented a clear overview on a new modulation technique employed in generating the pulses required to trigger the semiconductor devices used in multilevel inverters. By employing this new technique several distinct features of the symmetric and asymmetric MLI from the aspect of phase voltage is proved. The THD, DF, WTHD yields a better performance for asymmetric compared to symmetric MLI and this reduces the need for the output filter. Therefore, variable frequency PWM technique is a suitable method for asymmetric MLI which leads to reduced switching losses, THD and balanced switching actions. The proposed technique has been carried out in MATLAB/SIMULINK.

Y.Liu. et al, [13] they described an improved implementation of direct torque control (DTC) to a permanent magnet brushless DC drive (BLDC). The commutation torque ripple, which occurs every 60^0 elec. in a conventional 3-phase BLDC machine, with 120^0 elec. 2-phase conduction, is reduced by employing a hybrid 2-phase and 3-phase switching mode during the commutation periods. It is based on the criterion of minimizing the torque error between the commanded torque and the estimated torque, and does not require knowledge of the conduction duration of the 3-phase switching mode. During commutation periods at high rotational speeds, it combines the 2-phase and 3-phase switching modes which are automatically implemented by minimizing the torque error between the commanded torque and the estimated torque, and the torque ripple due to commutation events is reduced significantly, as has been demonstrated by both simulations and measurements.

Y. V. Aruna et al, [14] had presented, first Modeling of Four-Switch Inverter Fed Permanent Magnet Brushless DC Motor is done using Fuzzy controller with the Hall Effect sensors and then with sensor less control by adopting hysteresis current control method. Four-switch converter topology is introduced in this paper where cost saving is achieved by reducing the number of inverter power switches and also by eliminating the position Hall-effect sensors and phase shifters. The measured terminal voltages yields the virtual Hall signals for current commutation thereby giving a sensor less control. The current waveforms are rectangular without any distortion due to the hysteresis control. The performance of the PMBLDCM drive with reference to both the steady state and the dynamic conditions is improved with the application of the fuzzy logic controller.

T.Govindaraj et al, [15] has described 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

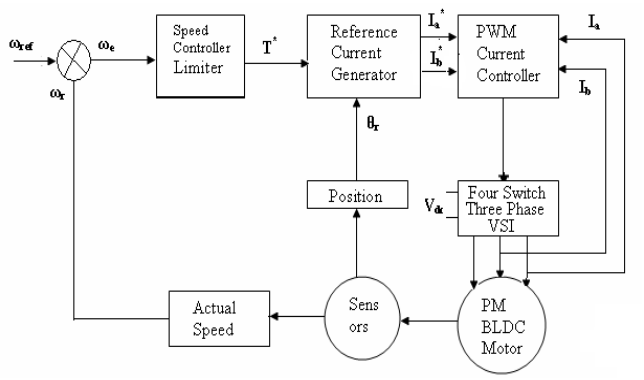
modulation scheme is designed and implemented to produce the desired dynamic and static speed–torque characteristics. The simulation model of the BLDC motor derive system with PI control based four switch three phase inverter on MATLAB/Simulink platform is presented. The performance of the developed 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.

III. SUMMARY OF LITERATURE REVIEW

Author	Method Used	Conclusion
G.Prasad et al,	BLDC Motor MATLAB/SIMULINK, EMF	Modeling is useful in studying the drive system before taking of the dedicated controller design.
R.Shanmugasundrm et al	BLDC drive; PWM control strategy	Low effect of electromagnetic interference and noise signals.
Vinodkumar Singh Patel et al	Hall position sensors , BLDC PWM, PI controller	Suppresses torque oscillations also the speed oscillations are minimized using closed loop system.
Jibin M Varghese et al	Four switch inverter, single neuron PI, current slopes	Algorithm is Easy, low cost due to reduced number of switches and current sensors
Y. V. Aruna	Fuzzy logic controller, PMBLDC Motor, sensor less control	Steady state and the Dynamic conditions is improved
T. Govindaraj et al	BLDC motor; four switch inverter.	Desired dynamic and static speed–torque characteristics

IV. PROJECT SCHEME METHODOLOGY

From the above literature review, the proposed methodology for the project is to be shown below.



V. CONCLUSION

From the above study, It was found that BLDC motor used in many applications and required rapid torque response and high–performance operation. It was found that PMSM and the BLDCM are similar in construction, their modeling takes different forms. The *d, q* model of the wound rotor SM is easily adapted to the PMSM while an *abc* phase variable model is necessary for the BLDC. Study the mathematical model of brushless DC motor also PID control based on the Ziegler-Nichols method is presented and PID controller is applied for closed loop speed control under various loading conditions. It was found that a simpler and more accurate current controlled pulse width modulation technique for brushless dc motors also realization of low cost and high performance three phase BLDC motor derive system. The proposed strategy shows good self adapted track ability also the structure of the drive is simplified.

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