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RESEARCH ARTICLE OPEN ACCESS

Speed Control of Brushless Dc Motor Using Direct Torque Control

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ABSTRACT: The faults The Brushless direct current (BLDC) motor is very popular compared with conventional dc motor. The BLDC motor uses an electronic commutator instead of mechanical commutator hence BLDC is more reliable than the conventional dc motor. A BLDC motor has same torque-speed characteristic as a conventional dc motor but the principle of operation is more complex. BLDC motors are commonly used in high goods such as refrigerator, washing machine, dish washer, high end pump applications which require higher reliability and efficiency, due to sensor less operation in large scale production industries such as the automotive, aviation parts manufacturing and processing industries etc.,

In this paper focusses on the implementation of direct torque control (DTC) to control the operation of BLDC Motor drives. Here, the direct torque control of BLDC motor is derived for open looped system and closed loop system using novel DTC. The speed control through variable applied voltage in open loop system and by using proportional integral (PI) in closed loop system for permanent magnet BLDC is simulated using MATLAB software. As compared with the most recent and highly performed DTC strategy, this one proposed strategy offers improved reliability due to the balancing of switching frequency of the inverter upper and lower insulated –gate bipolar transistors, and the reduction in the average value of the motor common mode voltage (CMV), and torque ripple is reduces during sector-to-sector commutations using three-level hysteresis torque controller. And the representation of the inverter voltage space vector. Simulated results are presented and it is shown that compared with conventional current control, DTC result is reduced torque ripple and a faster dynamic response for improving drives reliability of the motor.

KEY WORDS: BLDC, DTC, Suggested Controller.

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I. INTRODUCTION

The application of direct torque control to a three-phase BLDC drive to achieve instantaneous torque control and reduced torque ripple. This paper describes its application to brushless dc drives compared with conventional current control. DTC results in reduced torque ripple and a faster dynamic response. A simple and effective method of overcoming the problem of variable switching frequency and high torque ripple in DTC drives. By proper selection of the torque controller's parameters, the reverse voltage vector selection is avoided during torque reduction. Thus, the torque ripple is smaller compared to the hysteresis-based controller. An improved approach for reducing commutation torque ripple in DTC BLDC drives is proposed. The commutation torque ripple is analyzed, based on the approach which was presented and is minimized by combining the conventional two-phase switching mode with a controllable three-phase switching mode during periods when the phase currents are being commutated. It differs from the current control method. in that the exact duration of the three-phase switching mode is not required, since it is automatically determined by comparing the commanded torque with the estimated torque in the DTC implementation.

The proposed strategy consists in the synthesis of two vector selection tables suitably arranged considering the bus-clamping technique. Such synthesis depends on the rotation direction of the stator flux vector. Furthermore, it has been found that the proposed DTC strategy offers a lower harmonic distortion of the motor phase currents and a higher capability the reference stator flux vector. Therefore, reduction of the inverter switching to operate at low levels of the dc-bus voltage, which could be of interest for electric vehicle (EV) and hybrid electric vehicle (HEV) applications.

II. CONSTRUCTION AND OPERATION

First, BLDC motors are type of self-synchronous motors because the magnetic field generated by the stator and the rotor rotate at the same frequency. Hence, BLDC motors do not experience the slip that is normally seen in induction motor. The stator looks a lot like that of an induction motor, however the windings are distributed in different mannered. BLDC motors come in single phase and 3 phase configurations, corresponding to its type the stator has the same number of windings, out of these 3 phase motors are the most popular and widely used because they generate high torque and mostly used in high power applications. The brushless motor has surface mounted magnet on the rotor unlike the DC brushed motor; the stator of the motor is composed of stationary electromagnets. The major advantage of brushless motor is that the rotor carries only the permanent magnets; it needs no power at all. No connections need to be done with rotor; thus, no brush commutator pair needs to be made. Just because it requires no brushes so it is called brushless motor. One of the advantages of BLDC motor is that it does not require carbon brushes which wear off very fast hence it can perform noiseless and spark free operation. Moreover, brushless motors are more competent in terms of power consumptions. There is difference in the theory of operation of brushed DC motors with permanent magnets like how the commutator is made, and how the coils changes polarity during rotation. But brushless motor has no commutator no brushes. Thus, there are several ways to find out where the rotor is? Sometimes using rotary encoders, along with their controllers and know exactly the angle the rotor is, others use hall sensor. The hall sensor is placed in suitable position. Usually three hall sensors are used which are placed at 120˚ electrical apart from each other. It can sense if in front of it is the North or South Pole correspondingly the hall sensor will give high or low signal to the controller of the motor. The controller will then switch on or off the appropriate coils needed in order to produce rotating flux and provide torque.

III. THREE PHASE BRIDGE INVERTER (1200 CONDUCTION)

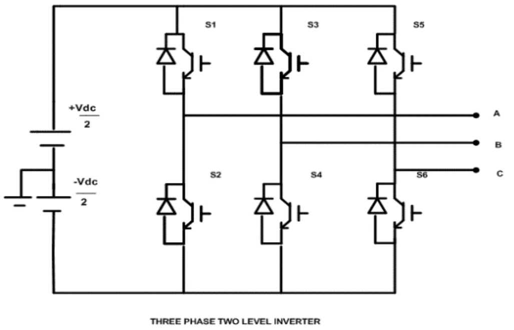

Fig. 1 Three Phase Bridge Inverter

Three-phase inverter, like single phase inverter take their dc supply from battery or more usually from rectifier. A rectifier converts AC voltage into dc voltage which fed to inverter. A three-phase inverter is a six-step bridge inverter [6]. It uses a minimum of six switches, switches can be thyristor, IGBT and MOSFET depends upon firing frequency and power supply. Turning ON or OFF these switches is controlled externally. Each step would be 60˚ interval for a six-step inverter. These switches are gated at 60˚ interval in proper sequence to produce 3 phase AC at output of inverter. A large capacitor connected at the input terminal tends to make the input DC voltage constant also suppresses the harmonics fed back to the dc source. There are two types of three phase bridge inverter one is 120˚ conduction mode another is 180˚ conduction mode, in 120˚ each switch conducts for 120˚ cycle and in 180˚ each switch conducts for 180˚ cycle. But in both these modes commutation take place every 60˚ electrical for completing one electric cycle of voltage at output.

IV. DTC STRATEGY

DTC strategies allow a direct control of BLDC motor drives variables through a selection of the inverter control signals, in order to fulfill the requirements as whether the electromagnetic torque needs to be increased or decreased. These decisions are achieved according to the output of the three level torque hysteresis controllers and the position of the flux vector in the α-β plane. The flux remains almost constant.

(i) In this closed loop system, the sector selector allows the identification of sector in which the stator flux vector lies in the α-β plane. It is based on the combination of the three Hall-effect signals of three phases.

(ii) The two –level hysteresis controller in the torque is replaced by a three-level hysteresis controller for a high-speed operation and during sector to sector commutations.

(iii) The switching frequency of the lower IGBTs is higher than that of the upper IGBTs which creates to an unbalanced operation of the inverter switches.

(iv) A high common mode voltage is due to the three phase voltages $v_{a0,}v_{b0,}v_{c0}$ have positive average values due to the unbalanced switching frequencies of upper and lower IGBTs. The reliability of inverter is compromised by the unbalanced switching frequencies of the upper and lower IGBTs.

(v) This proposed an improved DTC strategy to minimize the torque ripple amplitude during sector-to-sector commutations. At the beginning of each sector to force the turned off a phase current to flow through a controllable IGBTs instead of an uncontrollable freewheeling diode.

Thus, rising rate d_i / d_t of the turned off phase current can be regulated to be similar to that of the turned-on phase current. This proposed DTC strategy exhibits a capability to reduce the torque ripple during sector to sector commutations without any dependence on $V_{dc,} I, \Delta t,$ and L_s.due to substitution of the two-level torque controller by a three-level torque controller. The third level is activated when the torque falls during sector-to-sector commutations.

V. PROPOSED DTC STRATEGY

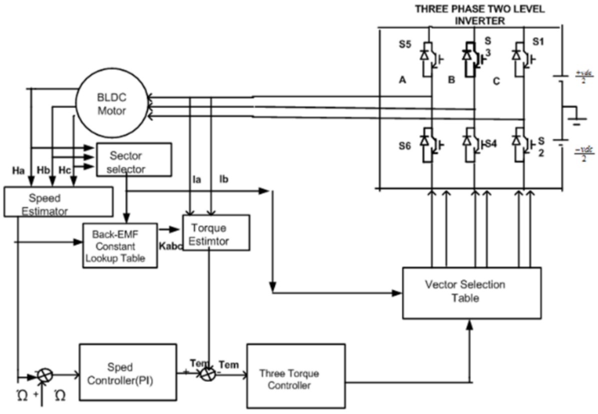

Fig. 2 Implementation scheme of the proposed DTC Strategy

The proposed DTC strategy is based on two major improvements. The first one is aimed at the drive reliability improvements

1. Equilibrate the switching frequencies of the inverter upper and lower IGBTs
2. Eliminate the CMV drawback within the BLDC motor.

The second modification is based on replacing of the two-level hysteresis controller in the loop by a three –level hysteresis controller in order to achieved the application of active voltage vector corresponding to the three-phase conduction mode during sector-to-sector commutations.

VI. TORQUE CONTROL OF BRUSHLESS DC MOTOR

Torque is another important parameter of the electric machine. Torque of fan motor is constant as the fan is running. Torque can be controlled by adjusting the magnetic flux. However magnetic flux is dependent upon the current flowing through the winding. Thus, by controlling current, torque of a motor can be controlled as shown in A PI loop similar to that used to control speed can be implemented to smooth the torque response curve with changes in load.

VII. CONTROLLER SIMULATION

In Open loop control system Hall effect sensor senses the North Pole or South Pole in front of it by giving high signal or low signal respectively as shown in Fig. 3.1. These hall sensors are placed at 120˚ electrical apart to complete one 360˚ electrical revolution. There are total six possible combinational outcomes of hall sensor 100,101,011,001,010,110. These signals tell when commutation will take place also sequence in which stators should be energies to produce rotating magnetic field. Commutation occurs when these signal changes. These signal changes every 60˚ electrical revolution, Hence the commutation take place every 60˚ electrical revolution. Once hall signals are received the gate logic circuit tells which two switches will be turn on. Gate logic is nothing but combination of AND gates and NOT gates. The gate logic can be derived from Karnaugh map. As we know there are total six switches of inverter each switch is on for 120˚ electrical revolution. In a MATLAB / SIMULINK Simulation –

(a) The main power circuit: Constant DC voltage source which provide 115V to driver circuit.

(b) The motor: The module “Permanent magnet synchronous motor” is selected with the waveform of air gap magnetic flux density being trapezoidal and the width of its flux part is 120 electrical.

(c) Measurement unit: this unit consists of bus selecting module “Bus selector,” which is used to measure the variables of the motor when it operating such as back EMF, current, rotor speed, torque etc.,

(d) Logic unit: This unit consists of logical operator AND/NOT which are used for generating gate pulse signals for driving circuit.

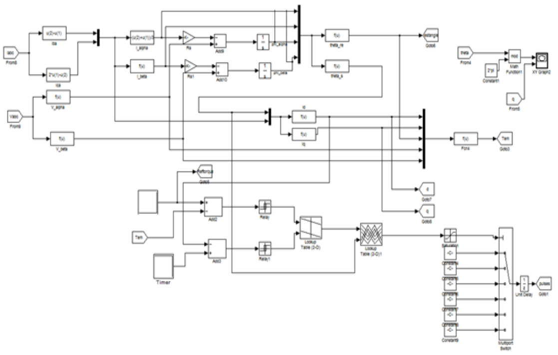

Fig. 3 Open Loop Control Simulation

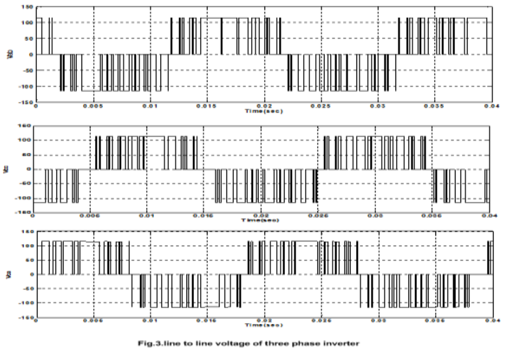

Fig. 4 Inverter voltage versus Time

Table 1 shows the input parameters of BLDC motor for simulation.

S. No	Motor Parameter	Specifications
1	Mechanical input	Torque Tm
2	Stator phase resistance Rs (ohms)	0.315
3	Stator phase inductance Ls (Henry)	1.4e-3
4	Voltage constant(Vpeak/rpm)	67
5	Torque constant(N.m/Apeak)	0.5568
6	Back EMF flat area (degree)	120
7	Inertia (Jkgm2)	0.0008
8	Friction factor F (N.m-s)	0.001
9	Flux linkage established by magnets	0.0928

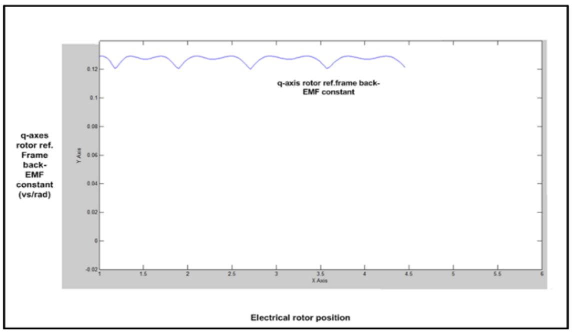

Fig. 5 Actual q-axis rotor reference frame back EMF constant vs electrical rotor position

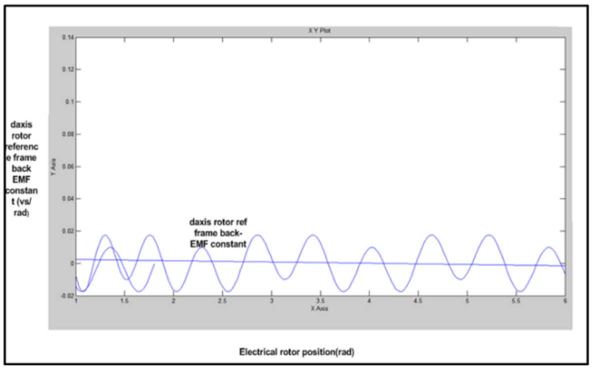

Fig. 6 Actual d- axis rotor reference frame back EMF constant versus electrical rotor position

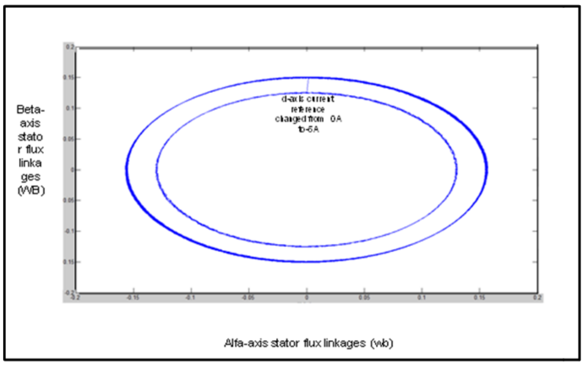

Fig. 7 Stator flux linkages trajectory of DTC of a BLDC motor

In closed loop control the speed of BLDC motor can be controlled using proportional integral (PI) controller, PI controller can regulate the duty cycle hence control the voltage applied to BLDC motor. Speed of BLDC motor is directly proportional to applied voltage. Speed of BLDC motor can be set to reference speed. Any diversion from this speed will be given as an error signal to PI controller. PI controller will take appropriate signal on receiving of this error signal; it can increase as well as decrease the duty cycle of applied gate signal. The MATLAB / SIMULINK Simulation is as follows—

a) The main power circuit: constant DC voltage source which provide 24V to driver circuit.

b) The motor: the module “Permanent magnet synchronous motor” is selected with the waveform of air gap magnetic flux density being trapezoidal and the width of its flux part is 120 electrical.

c) Measurement unit: this unit consists of bus selecting module “Bus selector,” which is used to measure the variables of the motor when it operating such as back EMF, current, rotor speed, torque etc.

d) Logic unit: this unit consists of logical operator AND/NOT which are used for generating gate pulse signals for driving circuit.

e) Controller unit: this unit consist of proportional integral controller, signal generator, relational operator.

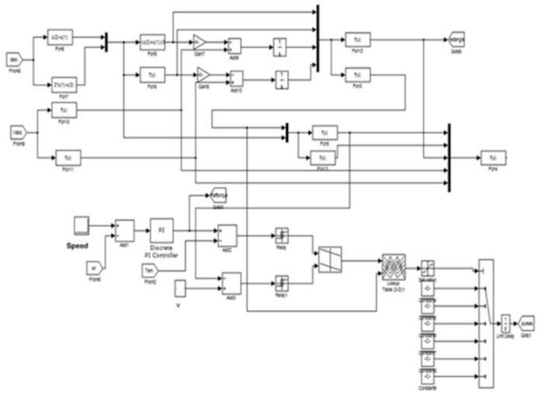

Fig. 8 Layout of closed loop

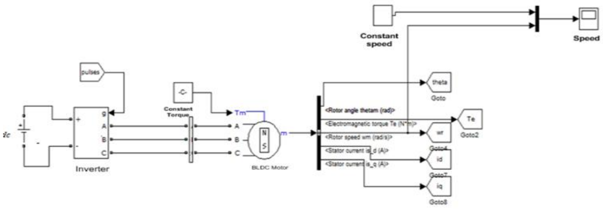

Fig. 9 BLDC model for closed loop control

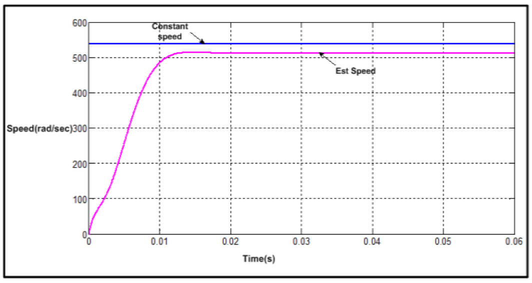

Fig. 10 speed Vs Time characteristics

Table 3.2 shows the input parameters of BLDC motor for simulation

S. No	Motor Parameter	Specifications
1	Mechanical input	Torque Tm
2	Stator phase resistance Rs (ohms)	0.315
3	Stator phase inductance Ls (Henry)	1.4e-3
4	Voltage constant(Vpeak/rpm)	67
5	Torque constant(N.m/Apeak)	0.5568
6	Back EMF flat area (degree)	120
7	Inertia (Jkgm2)	0.0008
8	Friction factor F (N.m-s)	0.001
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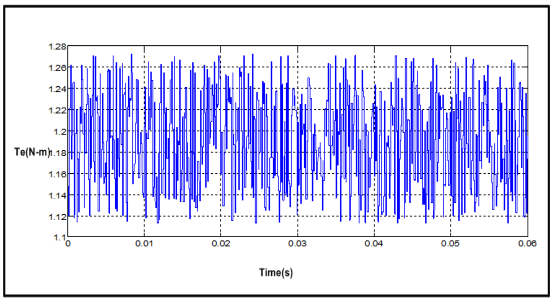

Fig. 11 Torque Vs time characteristics

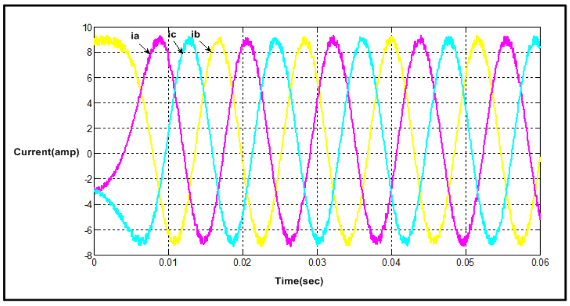

Fig. 12 Phase current waveform

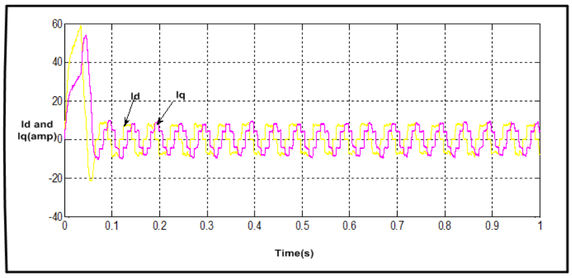

Fig. 13 I_d-I_q Vs Time waveform

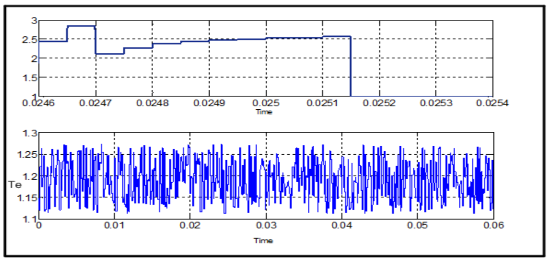

Fig. 14 Sector succession and electromagnetic torque Vs Time (sec)

From speed versus time graph it can be shown that control loop system is insensitive to parameter variation or disturbances. The speed maintained by motor is the reference speed.

VIII. CONCLUSION

This project provides for the detailed analysis of Direct Torque control of the BLDC motor by using open loop and closed loop mode. From the analysis it has been seen that the BLDC motor operation under close loop is not much affected compared with the open loop system.

REFERENCES

[1]. Yong Liu ; Z.Q. Zhu ; D. Howe , "Direct torque control of brushless DC Drives with Reduced Torque Ripple IEEE transactions on industry applications, vol. 41, no. 2, March/April 2005, pp. 599 - 608.

[2]. J. R. Hendershort Jr and T. J. E. Miller, Design of Brushless Permanent-Magnet Motors. Oxford, U.K.: Magana Physics/Clarendon, 1994.

[3]. P. J. Sung, W. P. Han, L. H. Man, and F. Harashima,"A new approach for minimum-torque-ripple maximum-efficiency control of BLDC motor,"IEEE Trans. Ind. Electron., vol. 47, no. 1, pp. 109–114, Feb. 2000.B. Clegg, Underground Cable Fault Location, McGraw Hill Book Company Europe, 1993.

[4]. Zhang and H. Yang, "Model Predictive Torque Control of Induction Motor Drives With Optimal Duty Cycle Control," IEEE Transactions on Power Electronics, vol. 29, no. 12, pp. 6593–6603, Dec 2014.

[5]. Zhang, D. Xu, J. Liu, S. Gao, and W. Xu, "Performance Improvementof Model-Predictive Current Control of Permanent Magnet SynchronousMotor Drives,"IEEE Transactions on Industry Applications, vol. 53,no. 4, pp. 3683–3695, jul 2017.

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