Direct Torque Control of Brushless DC Motor Using PI and FuzzyController

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Abstract— Permanent Magnet Brushless DC Motor (PMBLDC) is one of the main component in electrical drives due to increased efficiency, less noise,high life time and less maintanence. The combination of power semiconductor switches and permanent magnet (PM) materials has resulted in increased use of brushless DC motors in several applications such as industrial robots, actuators ect. In the existing methods the control of stator current in a brushless DC motor is successful under low speed conditions only. Under high speed conditions such control results in commutation torque ripple. This paper presents the direct torque control using PI and Fuzzy controller for minimizing torque ripples of BLDC motor. The BLDC motor is fed from the inverter where the rotor position and current controller is the input. Effectiveness of the proposed control method is verified through MATLAB/SIMULINK

Keywords— DTC, BLDC Motor, Electromagnetic Torque, variable speed drive, position sensors.

I. INTRODUCTION

Permanent magnet machines are applicable in key applications of critical importance, such as aerospace industry, tool drives and electric vehicle driving system since these needs to supply to servo applications. Due to this the importance of accurate control with fast response becomes mandatory and vital. Also, these applications necessitate the torque speed characteristics to be superior and load density to be low. The inbuilt disadvantages of typical DC machines which demand the utilization of mechanical brushes and problems associated with commutator has made the use of these motors inevitable to high performance applications.In this paper PMBLDC Motor, which can provide high torque for high acceleration and deceleration rates is examined for its operation with motor parameters including reluctance variations and other magnetic saturation effects.

The PMBLDC drive system which involves naturally an inverter controller arrangement which controls the duty cycle of the six switch inverter using PWM technique. Brushless dc motor (BLDCM) has been broadly used in industrial applications that require high reliability and accurate control due to its simple structure.The performance of such motors has been significantly improved due to the great development of power electronics, microelectronics.yet commutation torque ripple, which typically occurs owing to the loss of exact phase current control, is one of the major issue in BLDCM. So far, many techniques have been performed to reduce commutation torque ripple. A new control technique of BLDC was developed as Direct Torque Control (DTC). Using DTC it is possible to obtain a good dynamic control of torque without any mechanical transducers.

II. STUDY OF COMMUTATION TORQUE RIPPLE IN BLDC DRIVES

Idealized back-EMF and current waveforms for a 120◦-elec.-conduction-mode three-phase BLDC drive are shown. Since it can produce a higher electromagnetic torque per ampere than that which results with three-phase 180◦ elec. conduction, it is the most frequently used mode and thus, it is considered in this work. The principle of DTC when applied to a BLDC drive is described the current and torque ripple which result due to commutation events in a 120◦-elec.-conduction three-phase star-connected BLDC drive are analyzed, in a similar way to that given in a controllable three-phase switching mode is then introduced during the commutation periods, and the resulting current and torque ripple are analyzed[8]. Finally, the two operating modes are combined to minimize the commutation torque ripple in a DTC BLDC drive.

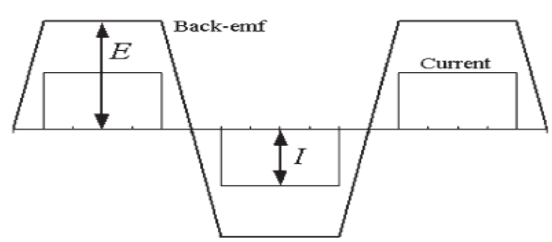

Fig. 1 Idealized back-EMF and current waveforms in BLDC drive.

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III. METHOD OF DIRECT TORQUE CONTROL

Direct torque control was developed for induction machine drives and it is directly controls the flux

TABLE 1

SWITCHING TABLE FOR DTC

C_Ψ	C_T	Sector I	Sector II	Sector III	Sector IV	Sector V	Sector VI
	1	V_2(110)	V_3(010)	V_4(011)	V_5(001)	V_6(101)	V_1(100)
1	0	V_7(111)	V_0(000)	V_7(111)	V_0(000)	V_7(111)	V_0(000)
	−1	V_6(101)	V_1(100)	V_2(110)	V_3(010)	V_4(011)	V_5(001)
	1	V_3(010)	V_4(011)	V_5(001)	V_6(101)	V_1(100)	V_2(110)
0	0	V_0(000)	V_7(111)	V_0(000)	V_7(111)	V_0(000)	V_7(111)
	−1	V_5(001)	V_6(101)	V_1(100)	V_2(110)	V_3(010)	V_4(011)

and electromagnetic torque, taking into consideration the electrical machine, the power electronic inverter.A relationship is established between the torque ,the flux and the optimal inverter switching so as to achieve a fast torque response .it exhibits better dynamic performance compared with this conventional control methods, such as vector control, is less sensitive to parameter variations.

To control the motors unpredictable incidence method is frequently used in all industries. In this method to get the excellent vibrant performance of direct torque control is prefer. Based on this measured stator voltage and currents the flux and torque is calculated. And the affiliation is recognized to obtained flux and torque. This method uses two stages to calculate the necessary quantities. In the first stage, the stator voltages is integrated to estimate the stator flux and the measured motor currents and obtained stator flux linkage is cross producted to obtain the torque quantity. Depending upon the projected values of the torque and stator flux the signals are generated, if error exists. Hence the dynamic response and torque control is established successfully.

VI. PI CONTROLLER

The combination of proportional and integral terms is important to increase the speed of the response and also to eliminate the steady state erro. The PI controller will reduce forced oscillations and steady state error resulting in operation of on-off controller. However, introducing integral method As the name suggests in integral controllers the output directly proportional to the integral of the error signal. Now we can analyze integral controller mathematically. As we know in an integral controller output is directly proportional to the integration of the error signal.Thus, PI controller will not increase the speed of response. It can be expected since PI controller does not have means to predict what will happen with the error in near future. This problem can be solved by introducing derivative mode which has ability to predict what will happen with the error in near future and thus to decrease a reaction time of the controller.

PI controllers are used in many industry, especially when speed of the response is not an matter. A control without D mode is used when:

- Fast response of the system is not required
- Large disturbances and noise are present during operation of the process
- There is only one energy storage in process

IV. TWO-AND THREE-PHASE SWITCHING MODES

In the two-phase switching mode, since the upper and lower switches in a phase leg may both be simultaneously OFF, irrespective of the state of the associated free-wheel diodes. Six digits are required to represent the states of the inverter switches, one digit for each switch. Thus, the voltage space vectors *V*1, *V*2, . . . , *V*6 are represented as switching signals (100001), (001001), (011000), (010010), (000110), and (100100), respectively, where from left to right, the logical values designate the states of the upper and lower switching signals for phases A, B, and C, respectively.

In the three-phase switching mode, all three phases are conducting at any instant, the upper and lower switches in each leg operate in tandem modes, and the voltage space vectors can be represented by three digits. These fully represent all the states of the inverter switches, since only one digit is required for each switching leg, as the upper and lower switches operate in tandem mode.

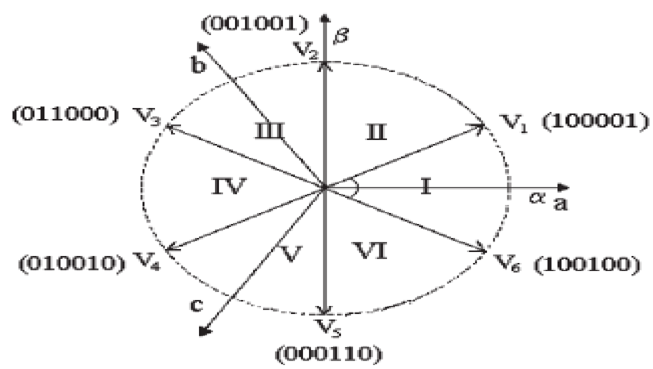

Fig. 2 Sectors of circular voltage vector locus**.**

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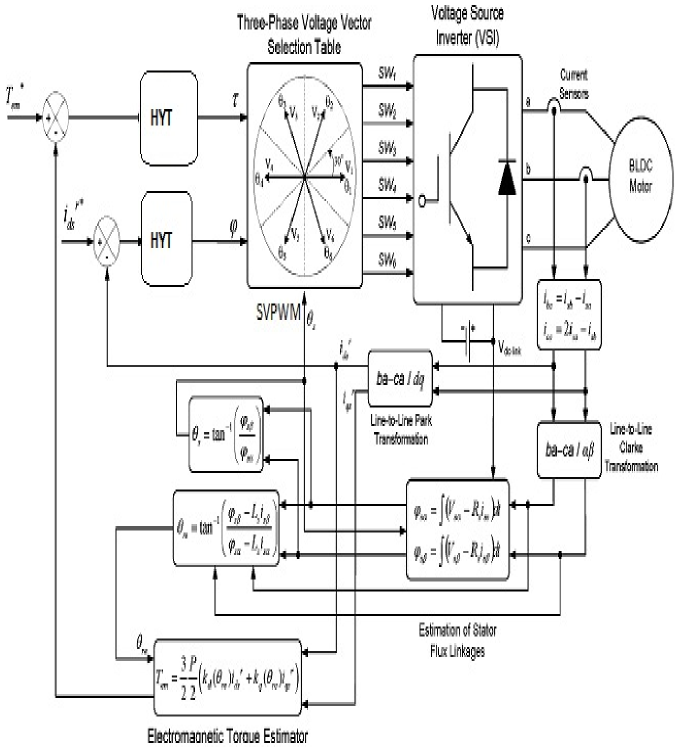

Fig. 3 Block diagram of DTC BLDC drive

VI. FUZZY LOGIC CONTROLLER

Fuzzy Logic Controller is an suitable inputs which will be fed to the same. These input variables should be such that, they represent the dynamical system completely. Then the function of the Fuzzifier comes into picture. Instead of using numerical variables, Fuzzy logic uses linguistic variables for processing information. But since the inputs to the FLC are in the form of numerical variables, they need to be converted into linguistic variables. This function of converting these crisp sets into Fuzzy sets is performed by the Fuzzifier.

The Fuzzification technique involves outlining the membership functions for the inputs. This Membership Functions (MF) should cover the whole universe of discourse and each one represents a Fuzzy set or a linguistic variable. The crisp inputs are thus transformed into fuzzy sets. Triangular MF, Trapezoidal MF, Bell MF, Generalized Bell MF or Sigmoidal MF can be used. Even a hybrid of any of the above Membership Functions can be used for Fuzzification.

TABLE 2

FUZZY RULE BASE TABLE

Δe \ e	NB	NS	Z	PS	PB
NB	NB	NB	NB	NS	Z
NS	NB	NS	NS	Z	PS
Z	NB	NS	Z	PS	PB
PS	NS	Z	PS	PS	PB
PB	Z	PS	PB	PB	PB

VII. SIMULATION RESULTS

Brushless dc motor input voltage is connected to an inverter circuit and then it is connected to BLDC motor the motor output is connect with bus and then electromagnetic torque and speed will be connected to an scope. Hall sensor is used to sense the motor speed 1.1,50Hz BLDC motor is connected to scope.

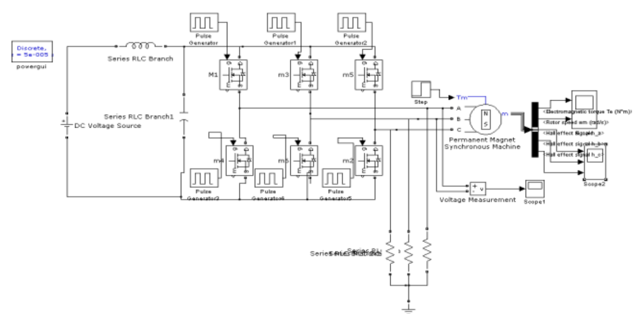

Fig.

Fig.4 Brushless DC Motor Simulation Diagram

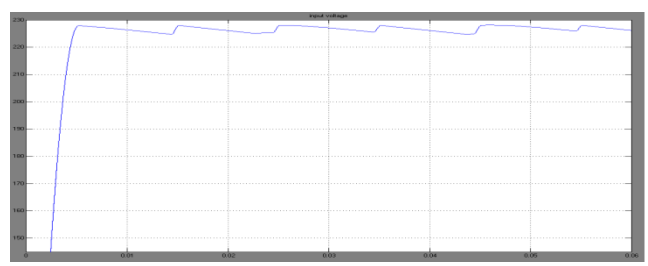

Fig. 5 Brushless DC Motor Input Voltage Waveform

Figure 5 shown as motor input voltage 230V voltage will be given to the motor and get nearly 230 volt it will be constant. This result shows inverter input voltage when we give input voltage the motor will be run at the same voltage it depends on the performance o the motor. At the time of starting the motor input voltage is 230 v and time is T(seconds) It takes some time to start.

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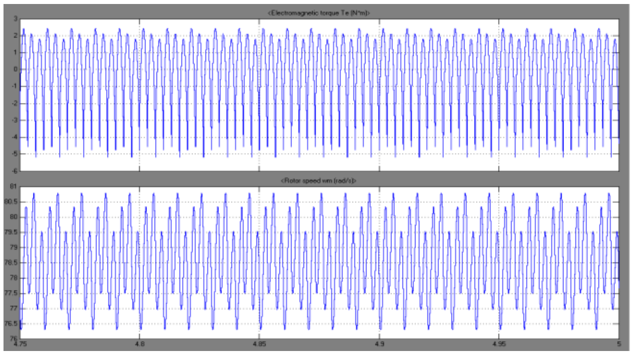

Fig. 6 Waveform of Electromagnetic Torque and Speed

Fig. 7 Hall sensor output waveform

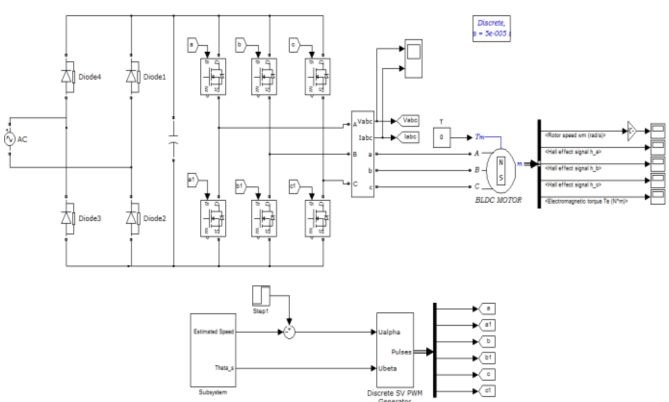

Fig. 8 Waveform of BLDC Motor

Here the AC source can be given to the Rectifier that can convert the AC source to DC and then it can be regulated by the capacitor then the single line current can be displayed in the first scope. After that the regulated dc current can be given to the IGBT block, The IGBT turns on when the collector-emitter voltage is positive and greater than V_f and a positive signal is applied at the gate input (g > 0). It turns off when the collector-emitter voltage is positive and a 0 signal is applied at the gate input (g = 0).

The IGBT device is in the off state when the collector-emitter voltage is negative. Note that many commercial IGBTs do not have the reverse blocking capability. Therefore, they are usually used with an anti-parallel diode. The modeling of brushless dc motor involves solving many simultaneous differential equations, each depending upon the inputs to the motor and the simulation constants. Simulation constants are values like the phase inductance that do not change during simulation. Therefore these parameters can be treated as constants during a simulation. However, the model provides for dialogue boxes that can be used to vary the values of these constants.

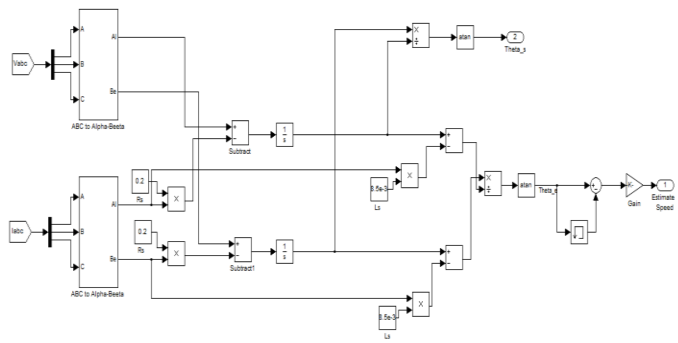

Fig. 9 Direct Torque Control Waveform

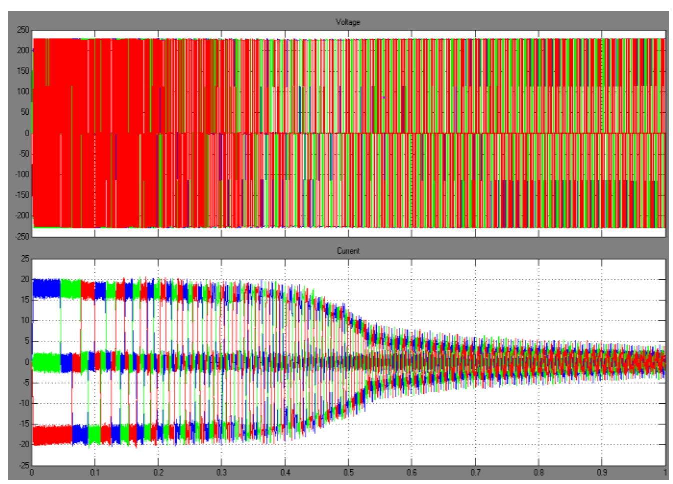

Fig. 10 Waveform of Voltage and Current

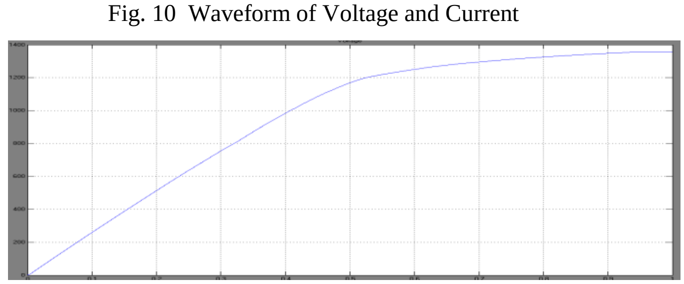

Fig. 11 Simulation Output For Speed

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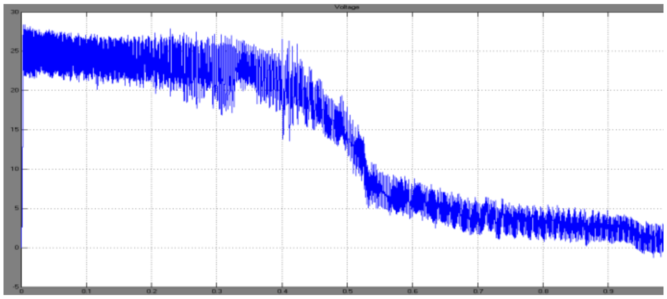

Fig. 12 Electromagnetic Torque

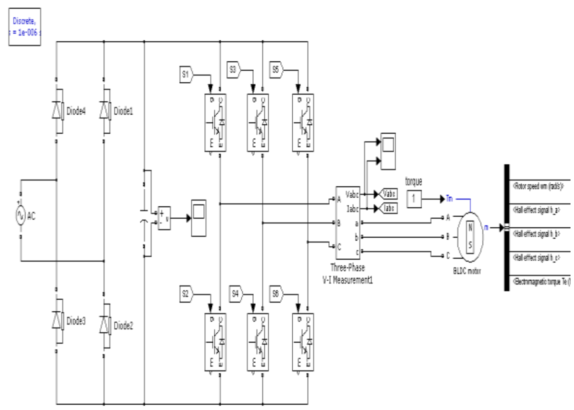

Fig.13 PI and Fuzzy Simulation Diagram

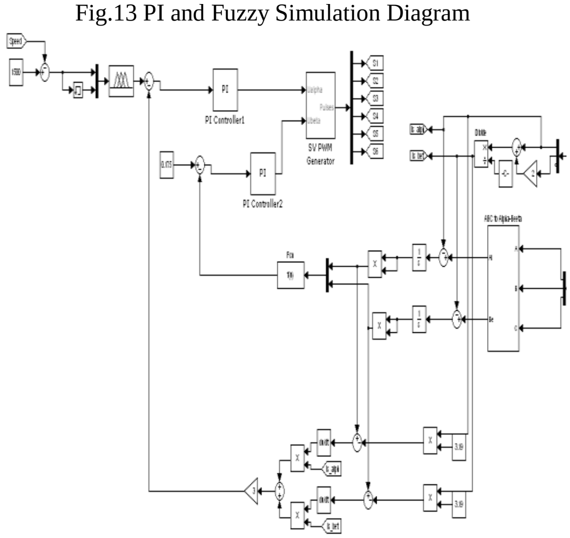

Fig.14 Fuzzy Subsystem

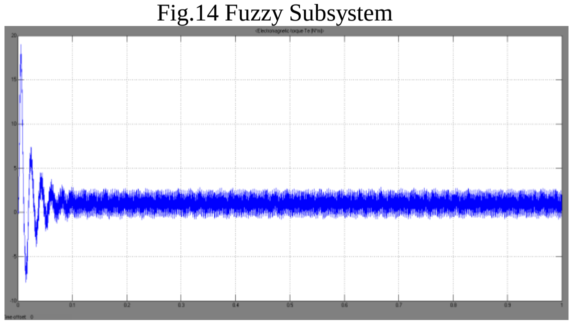

Fig.14 Electromagnetic Torque

VIII. CONCLUSION

The phase-current waveform and torque ripple which result during commutation events in a DTC two-phase 120◦-elec.- conduction permanent-magnet BLDC drive have been analyzed, and an improved DTC, PI and fuzzy logic controller has been proposed to minimize the commutation torque ripple. During commutation periods at high rotational speeds, it automatically combines two- and three-phase switching modes by minimizing the error between the commanded torque and the estimated torque. The torque ripple due to commutation events is, thereby, reduced significantly, as has been demonstrated by both simulation results.

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