Volume : 2 | Issue : 8 | Aug 2013 • ISSN No 2277 - 8160

Research Paper | Engineering

# Design and Performance Evaluation of Direct Torque and Indirect Flux Control of BLDC Motor

| | |
|---|---|
| C. Dinakaran | Assistant Professor, Department of EEE, SVCET, Chittoor, India |
| K. Bhavani | Assistant Professor, Department of EEE, SVCET, Chittoor, India |
| Prof. K. Eswaramma | Professor & Head, Department of EEE, SVCET, Chittoor, India |

**ABSTRACT**

*In this paper, the position-sensor less direct torque and indirect flux control of brushless dc (BLDC) Motor with non sinusoidal back electromotive force (EMF) has been extensively investigated. In the literature, several methods have been proposed for BLDC Motor drives to obtain optimum current and torque control with minimum torque pulsations. Most methods are complicated and do not consider the stator flux linkage control, therefore, possible high-speed operations are not feasible. In this study, a novel and simple approach to achieve a low-frequency torque ripple-free direct torque control (DTC) with maximum efficiency based on dq reference frame is presented.*

*The proposed sensor less method closely resembles the conventional DTC scheme used for sinusoidal ac Motors such that it controls the torque directly and stator flux amplitude indirectly using d-axis current. This method does not require pulse width modulation and proportional plus integral regulators and also permits the regulation of varying signals.*

**KEYWORDS: BLDC motor, direct torque control, fast torque response, Nonsinusoidal back electromotive force (EMF), stator flux control, Rotor flux control**

## I.INTRODUCTION

Energy is the basic necessity for the economic development of country. It must be developed and made available at the point of consumption in suitable form. But transporting the energy from its place of origin to the point of demand and of converting it into its final physical form is a difficult task. In many cases, these difficulties can be solved easily with an electrical intermediate stage because electricity can be generated from primary energy sources like chemical energy in fossil fuel, hydro energy, etc in a relatively efficient. Transported with minimum losses over long distance and distributed simply at an acceptable cost and also it can be converted into any final form at the point of destination.

About sixty percent of electricity is generated and converted into mechanical energy, which is required whenever physical activities such as process control, transportation, industrial process, etc takes place. Traditionally, separately excited dc machines were the obvious choice for applications in adjustable speed drives, where independent torque and flux control is required. In dc machine, the torque can be controlled over a wide range of speed by independent variation of field and armature currents. The dc machines also have excellent dynamic performance over a wide range of operating conditions. But due to inherent decoupling between field flux and armature current commutation problem will occur. On the other hand, dc machines are inherently bulky, require frequent maintenance, have low torque-to-weight ratio. The use of BLDC motors has steadily increased over the last several years as the cost of these motors and the technology to control these motors has decreased and the benefits of these motors over other motor types has become more important than just the initial cost.

The construction of a BLDC motor gives it several advantages when compared to other electric motors. First, since the BLDC uses electronic commutation it has a longer life when compared with brushed DC motors and requires less maintenance since the brushes on the motor do not require cleaning and replacement.

## II. BRUSH LESS (BLDC) MOTOR

Brushless Direct Current (BLDC) motors are one of the motor types rapidly gaining popularity. BLDC motors are used in industries such as Appliances, Automotive, Aerospace, Consumer, Medical, Industrial Automation Equipment and Instrumentation. As the name implies, BLDC motors do not use brushes for commutation; instead, they are electronically commutated. BLDC motors have many advantages over conventional DC motors and induction motors. A few of these are:

- Better speed versus torque characteristics
- High dynamic response
- High efficiency
- Long operating life
- Noiseless operation
- Higher speed ranges

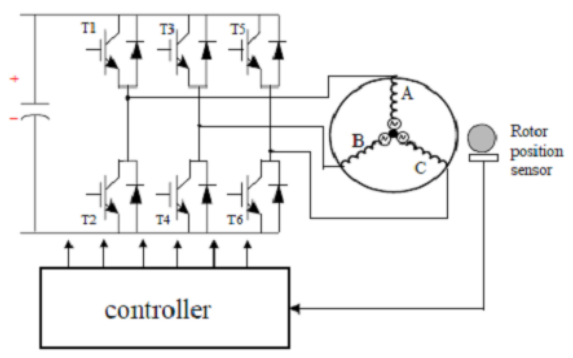


**Fig.1. Typical brushless dc motor control system**

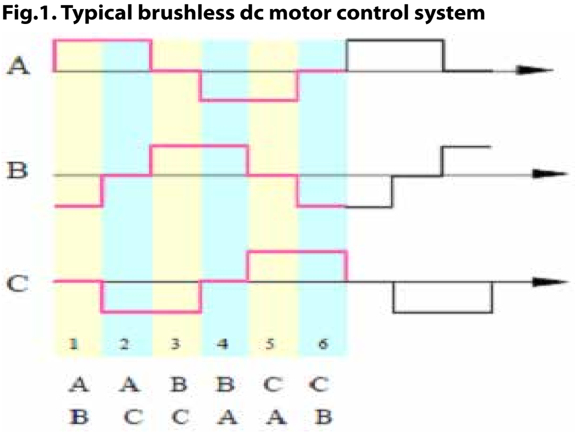


**Fig.2.Typical three phase current waveforms in the BLDC motor**

## III. DIRECT TORQUE CONTROL (DTC)

Direct Torque and Flux Control (DTFC), also termed Direct Torque Control (DTC), has been developed by German and Japanese researchers for use in torque control of high power servo drives. The publication of the DTC theory actually goes back to 1971. Recently, it has provided an industrial alternative to the field oriented control strategy. DTC is a control philosophy exploiting the torque and flux producing capabilities of ac machines when fed by a simple voltage source inverter that does not require current regulation loops, still attaining similar performance to that obtained from a vector control drive. Three control techniques have been employed for implementing DTFC drives: The Switching Table (ST), the Direct Self Control (DSC) and the Direct Vector Modulation Control (DVMC). ST and DSC regulators are of the hysteresis (discrete) type, whereas the DVMC digitally implemented analog controllers such as the PI controllers. For implementing the control loop, the actual stator flux (amplitude and orientation) and electromagnetic torque are calculated by an estimator from the stator voltages and currents in a similar fashion to the reconstruction approach of the direct vector control philosophies (DFOC and SFOC). The stator flux is an integral of the stator EMF,

$$\Psi s = \int (u_x - R_s i_s)dt$$
$$T_{el} = P(\Psi_s, \alpha i_s, \beta - \Psi_s, \beta i_s, \alpha)$$

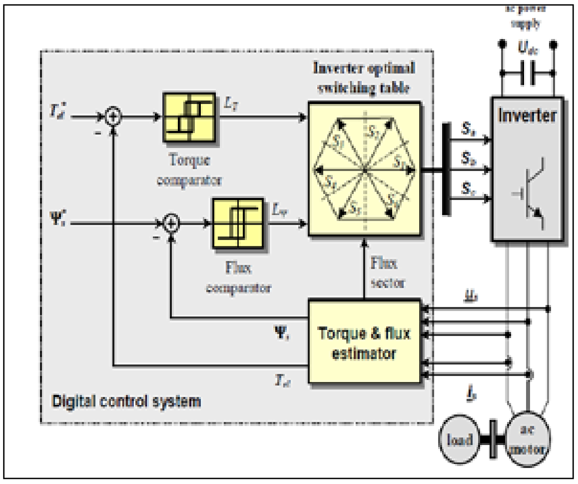


**Fig.3. Basic direct torque control scheme for ac motor drives (DTC)**

## IV. Field Oriented Control (FOC)

The vector control philosophy started to be developed around 1970. Several types of vector control are possible: rotor-oriented, rotor-flux-oriented, stator-flux-oriented and magnetizing-flux-oriented. The final objective of the vector control philosophy is to be able to control the electromagnetic torque in a way equivalent to that of a separately excited dc machine: Field-oriented control enables control over both the excitation flux-linkage and the torque-producing current in a decoupled way. However, only the rotor-flux-oriented control yields complete decoupling. Choosing a different flux orientation may outweigh the lack of complete decoupling for some special applications.

Thus, the electromagnetic torque generated by the motor can be controlled by controlling the q-axis current. This is equivalent to the torque control of a separately excited dc machine. As shown later, the rotor flux can be controlled independent torque and flux control of the ac machine making the control accurate in every operation point (steady state and transient). Fig.4 summarizes the basic torque control scheme with FOC.

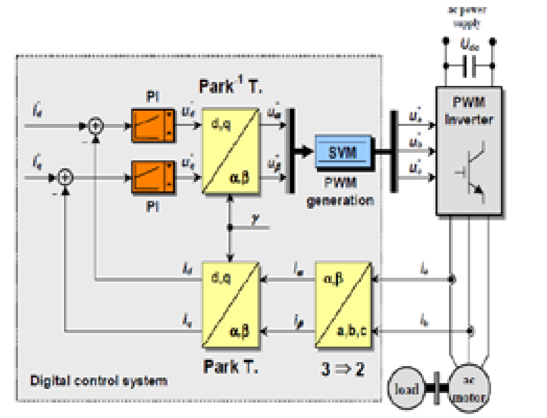


**Fig.4.Basic torque control scheme of FOC for ac motor drives.**

## V. ESTIMATION OF ELECTRICAL ROTOR POSITION

Electrical rotor position $\theta_{re}$, which is required in the line-to line Park transformation and torque estimation algorithm, can be found by

Fig.5 shows the Overall block diagram of the position-sensor less direct torque and indirect flux control (DTIFC) of BLDC motor drive using three-phase conduction mode.

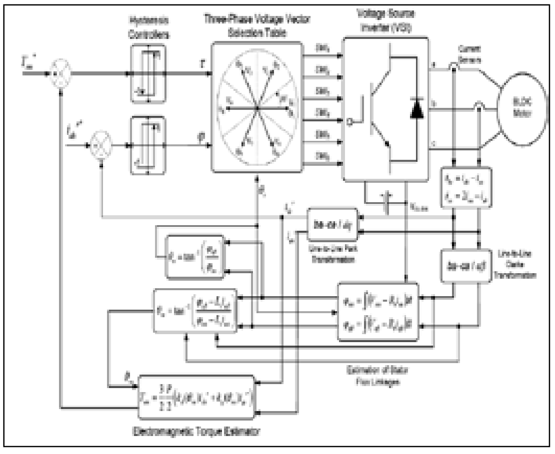

**Fig.5. Overall block diagram of the position-sensor less direct torque and indirect flux control (DTIFC) of BLDC motor drive using three-phase conduction mode**

## VI. SIMULATION RESULTS

### A. EXISTING METHODS OF DIRECT TORQUE AND INDIRECT FLUX CONTROL

### (a) DIRECT TORQUE CONTROL OF BLDC MOTOR USING SPEED CONTROLLER

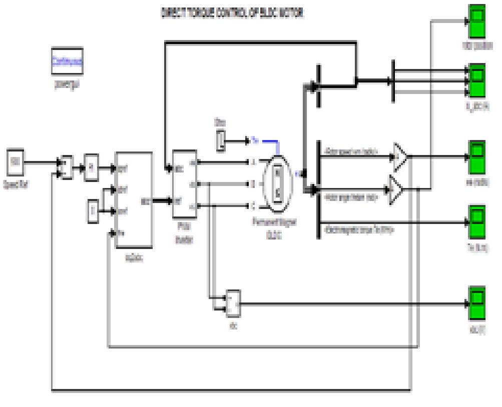

**Fig.6. simulation of direct torque control of BLDC motor using speed controller (N=500rpm)**

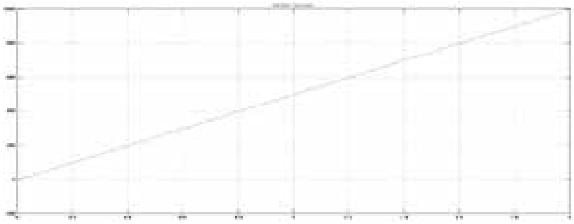

**Fig. Rotor position**

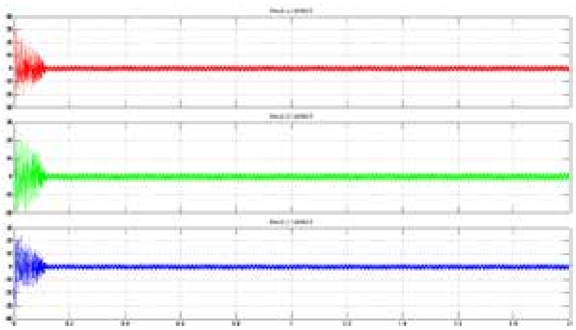

**Fig. Stator phase currents**

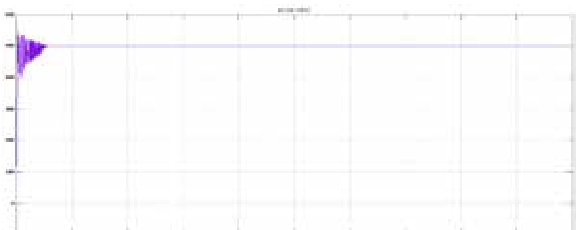

**Fig. Rotor speed (N=5oo rpm)**

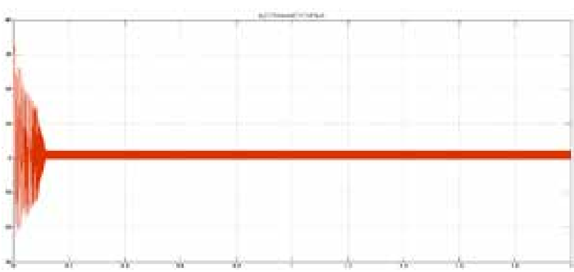

**Fig. Electromagnetic torque**

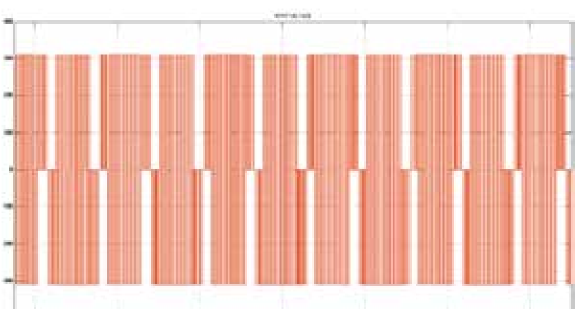

**Fig. Inverter voltage**

**(b) DIRECT TORQUE CONTROL OF BLDC MOTOR USING SPEED AND CURRENT CONTROLLER**

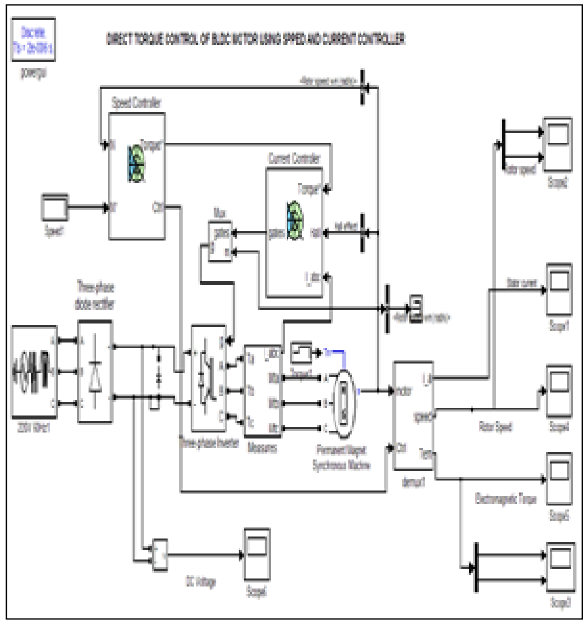


**Fig.7. Simulation of BLDC motor using speed controller and current controller (N=500rpm)**

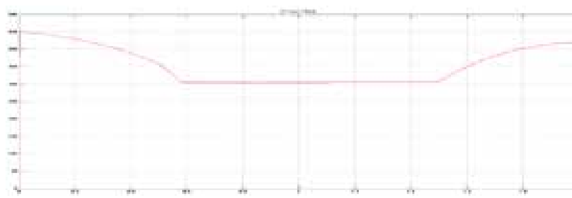

**Fig. DC input voltage**

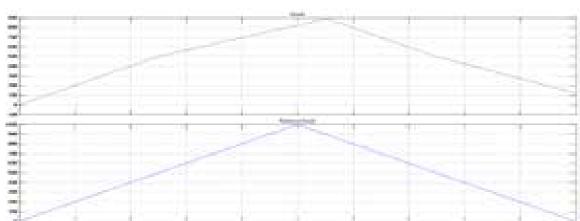

**Fig. Rotor reference and actual speeds**

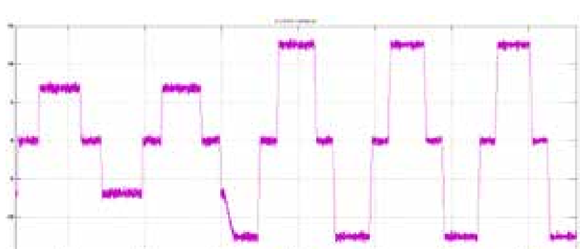

**Fig. Stator currents**

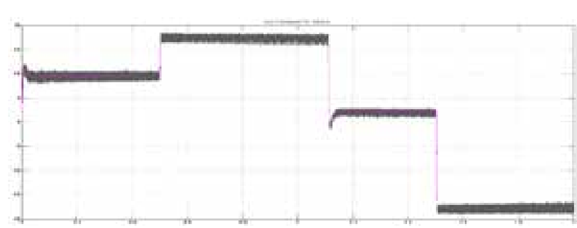

**Fig. Electromagnetic Torque**

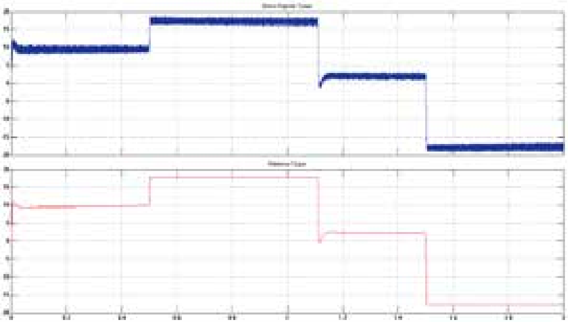

**Fig. Reference and actual torques**

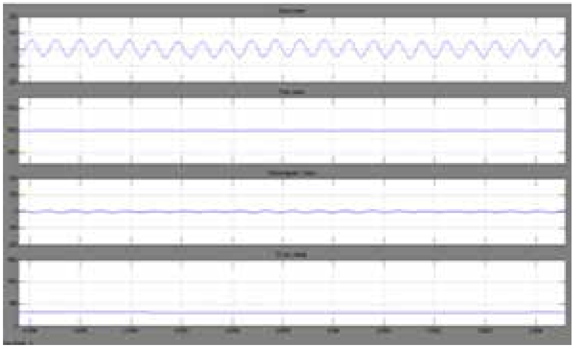

**Fig. Output waveforms of Stator current, Rotor speed, Electromagnetic torque, DC bus voltage**

## B. PROPOSED METHOD FOR DIRECT TORQUE AND INDIRECT FLUX CONTROL OF BLDC MOTOR

## (C) DIRECT TORQUE AND INDIRECT FLUX CONTROL OF BLDC MOTOR

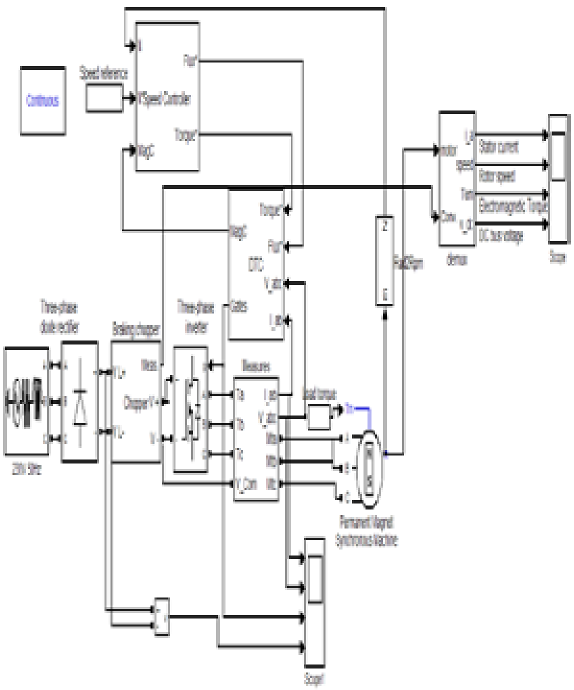


**Fig.8. Simulation diagram of direct torque and indirect flux control of BLDC motor**

### (d) DTC of simulation diagram

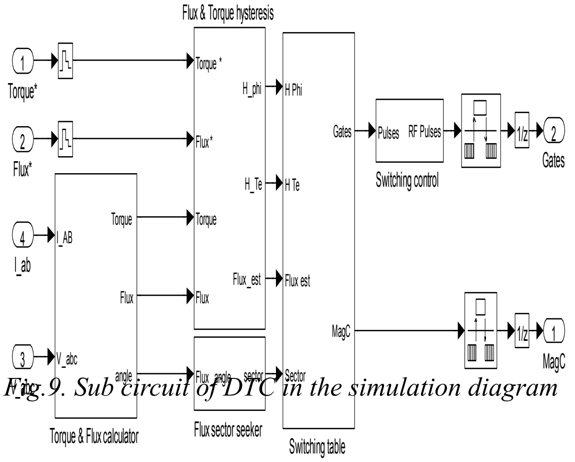


*Fig. 9. Sub circuit of DTC in the simulation diagram*

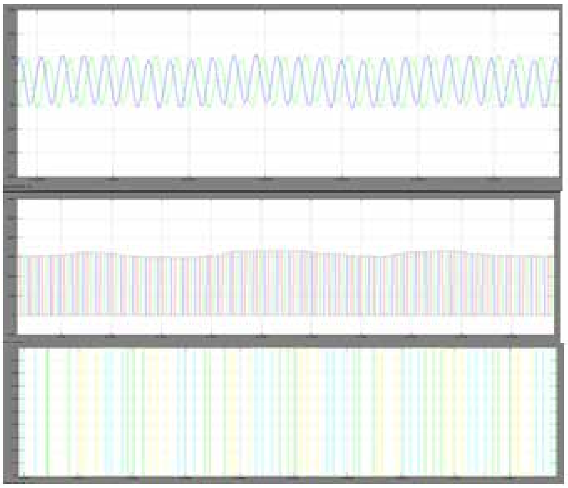

**Fig. Input waveforms Current ($I_{ab}$), Three phase voltage($V_{abc}$),Gate pulses, DC bus voltage**

## C. ELECTRICAL DESIGN OF THE HAEDWARE MODEL

### (e) Power Supply Diagram

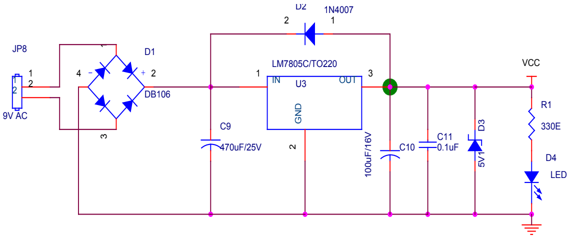


**Fig.10. Power supply diagram**

### (f) Driver circuit

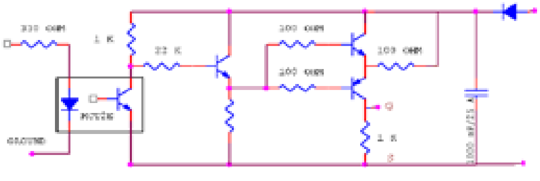


**Fig.11. Driver circuit**

## VII. HARDWARE MODEL KIT

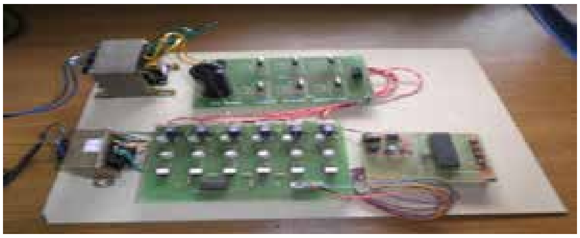

**Fig.12. Circuit diagram of the total hardware implementation of the direct torque and indirect flux control of BLDC motor**

**Fig. The input waveform of the three phase inverter circuit diagram**

**Fig. The gate pulse of the controller circuit**

**Fig. Output waveform of the three phase inverter**

## VIII. CONCLUSION

sensor less three-phase conduction DTC scheme for BLDC motor drives that is similar to the conventional DTC used for sinusoidal ac motors where both torque and flux are controlled, simultaneously. This method provides advantages of the classical DTC such as fast torque response compared to vector control, simplicity (no PWM strategies, PI controllers, and inverse Park and inverse Clarke transformations), and a position-sensor less drive. It is shown that the BLDC motor could also operate in the flux-weakening region by properly selecting the *d*-axis current reference in the proposed DTC scheme.

Electrical rotor position required in the torque estimation is obtained using winding inductance, stationary reference frame currents, and stator flux linkages. Since the actual back EMF waveforms are used in the torque estimation, low-frequency torque oscillations can be reduced convincingly compared to the one with the ideal-trapezoidal waveforms having 120 electrical degree flat top. A look-up table for the three-phase voltage vector selection is designed, similar to a DTC of PMSM drive to provide fast torque and flux control. Therefore, indirect stator flux control is performed by controlling the flux related *d*-axis current using bang-bang (hysteresis) control, which provides acceptable control of time-varying signals (reference and/or feedback) quite well in simulation and experimentally.

## REFERENCES

[1]. "Direct Torque and Indirect Flux Control of Brushless DC Motor" by Salih Baris Ozturk and Hamid A. Toliyat. | [2]. "Sensorless Direct Torque and Indirect Flux Control of Brushless DC Motor with Non-sinusoidal Back-EMF" BY Salih Baris Ozturk and Hamid A. Toliyat. | [3]. "Direct Back EMF Detection Method for Sensorless Brushless DC (BLDC) Motor Drives" by Jianwen Shao | "Brushless DC (BLDC) Motor Fundamentals" by L. Zhong, M. F. Rahman, W. Y. Hu, and K. W. Lim. | [4]. "Sensorless Brushless DC Motor Control with Z8 Encore Basic Theory of Direct Torque Control" P. J. Sung, W. P. Han, L. H. Man, and F. Harashima. | [5]. "Sensorless control of 3-phase brushless DC motors Direct Torque Control versus Field Oriented Control" by Y. Liu, Z. Q. Zhu, and D. Howe. |