

# Cogging Torque Minimization of BLDC Motor

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**Abstract** - Based on Cuk converter, a novel commutation torque ripple reduction strategy is proposed for brushless DC motor (BLDCM) in this project. Output modes (buck-boost mode and boost mode) of the Cuk converter during commutation period and normal conduction period are altered by designing a mode selection circuit, which can reduce commutation torque ripple over the entire speed range. During the commutation period, Cuk converter operates in the boost mode to step up the input voltage of three-phase bridge inverter and then meet the voltage demand of commutation period, such that the commutation torque ripple can be reduced by keeping the non-commutated current steady. In order to improve the utilization rate of the converter, during the normal conduction period, Cuk converter operates in the buck-boost mode and the input voltage of three-phase bridge inverter is regulated by adopting PAM (Pulse Amplitude Modulation) method without the inverter PWM chopping, which can reduce the voltage spike damage to the motor windings caused by turn-on/off of MOSFET in the inverter and simplify the program of modulation method further. The experimental results verify the correctness of the theory and the effectiveness of the proposed approach.

## Key Words:

### 1.INTRODUCTION

A drive is an electronic device that harnesses and controls the electrical energy sent to the motor. The drive feeds electricity into the motor in varying amounts and at varying frequencies, thereby indirectly controlling the motor's speed and torque. The speed of rotation of an electrical machine can be controlled precisely by implementing the concept of drive. The main advantage of this concept is, the motion control is easily optimized with the help of drive. In very simple words, the systems which control the motion of the electrical machines are known as electrical drives. This drive system is widely used in large number of industrial and domestic applications like factories, transportation systems, textile mills, fans, pumps, motors, robots etc. Drives are employed as prime movers for diesel or petrol engines, gas or steam turbines, hydraulic motors and electric motors. In this thesis the drive system is used to control the speed of the brushless DC motor.

Brushless motors fulfill many functions originally performed by brushed DC motors, but cost and control complexity prevents brushless motors from replacing brushed motors completely in the lowest-cost areas. Nevertheless, brushless motors have come to dominate many applications, particularly devices such as computer hard drives and CD/DVD players. Small cooling fans in electronic equipment are powered exclusively by brushless motors. They can be found in cordless power tools where the increased efficiency of the motor leads to longer periods of use before the battery needs to be charged. Low speed, low power brushless motors are used in direct-drive turntables for gramophone records. A drive is an electronic device that harnesses and controls the electrical energy sent to the motor. The drive feeds electricity into the motor in varying amounts and at varying frequencies, thereby indirectly controlling the motor's speed and torque. The speed of rotation of an electrical machine can be controlled precisely by implementing the concept of drive. The main advantage of this concept is, the motion control is easily optimized with the help of drive. In very simple words, the systems which control the motion of the electrical machines are known as electrical drives. This drive system is widely used in large number of industrial and domestic applications like factories, transportation systems, textile mills, fans, pumps, motors, robots etc. Drives are employed as prime movers for diesel or petrol engines, gas or steam turbines, hydraulic motors and electric motors. In this thesis the drive system is used to control the speed of the brushless DC motor.

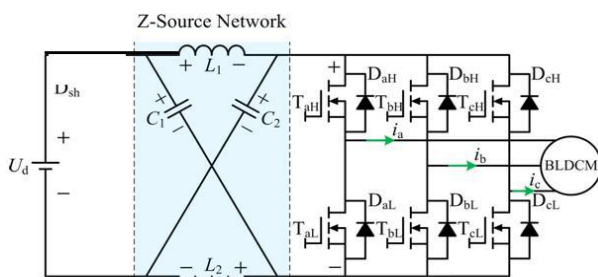
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## 2. METHODOLOGY

The inverter is fed with the dc supply through the Z-source impedance network. The output of the voltage source inverter is given to the BLDC motor. The three phase to two phase conversions are carried out in the transformation block. The torque estimator utilizes the necessary dq axis current, voltage and the necessary parameters to estimate the actual torque value. The speed error is given as the input to the fuzzy controller to generate the reference torque value. The rotor position is obtained through the back emf sensing method. The direct axis current reference and actual value are compared to obtain the flux error. The flux error, torque error and the rotor position are given as the control signals to the PWM generate to generate the gating pulses for the inverter.

### 2.1 Z Source Network

It is an impedance network coupled between the inverter and the power source. Its unique feature is to boost up the voltage from the battery without the need of boost converter or the step-up transformer



### 2.2 Torque Estimator

This block calculates the actual torque by using the equation,  
 $Torque = (3P/4\omega) * (e_d * i_d + e_q * i_q)$

The current and the voltage parameters are obtained from the transformation block. "P" represents number of poles and "ω" represents the angular velocity. It gives the actual torque value produced by the motor

### 2.3 Working

The permanent magnet brushless DC motor is fed by the AC source through the electronic commutator. A Z-source network is coupled between the DC supply and the inverter to boost up the supply thereby increasing the torque magnitude by reducing the ripples.

The direct torque control method is used to control the speed of the motor. The torque error, flux error and the rotor position are the three controlling signals used to generate the gating signals for the inverter. The motor three phase voltages and currents are transformed to the two phase quantities in the synchronously rotating frame using the park and Clarke transformations.

### 2.4 Fuzzy Logic Controller

Fuzzy logic expressed operational laws in linguistics terms instead of mathematical equations. Many systems are too complex to model accurately, even with complex mathematical equations; therefore traditional methods become infeasible in these systems. However fuzzy logics linguistic terms provide a feasible method for defining the operational characteristics of such system.

Fuzzy logic controller can be considered as a special class of symbolic controller

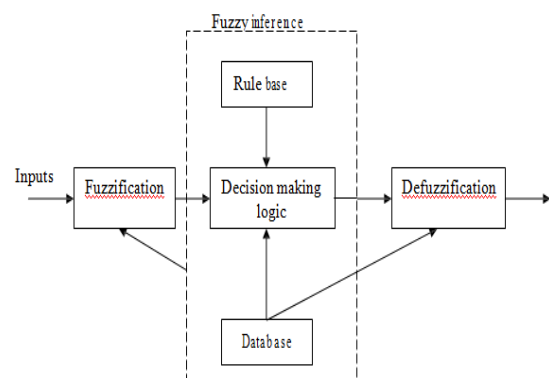


Chart -1: Fuzzy Logic Control

## 3. RESULTS AND DISCUSSION

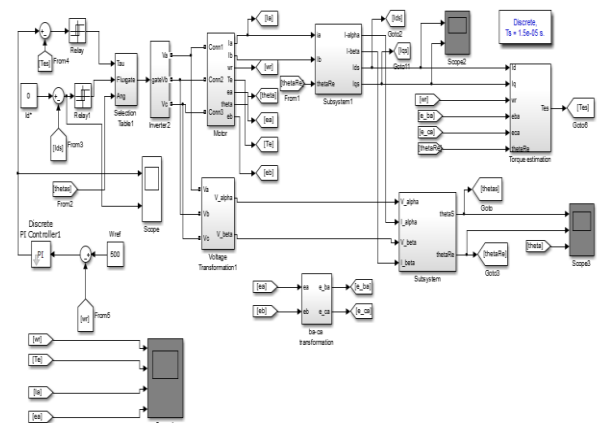


Fig -1: Z source network based DTC BLDC with PI controller MATLAB simulation

### 3.1 Z Source Network Inverter

The Z-source network is coupled between the voltage source and the inverter. The inverter operates as an electronic commutator

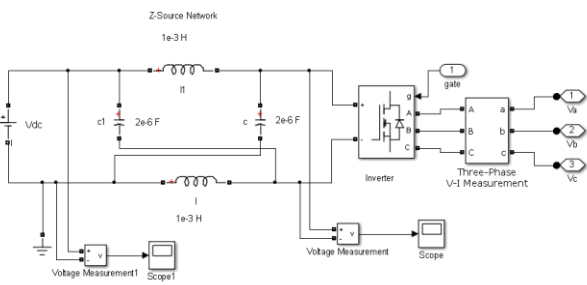


Fig -2: Z-source Network Inverter

### 3.5 Z Source Network Output DC Voltage

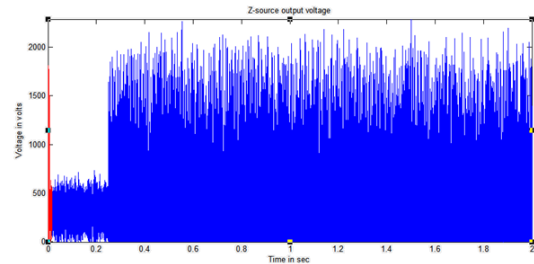


Fig -5: Z-source Network Output Waveform

### 3.2 Gating Pulses

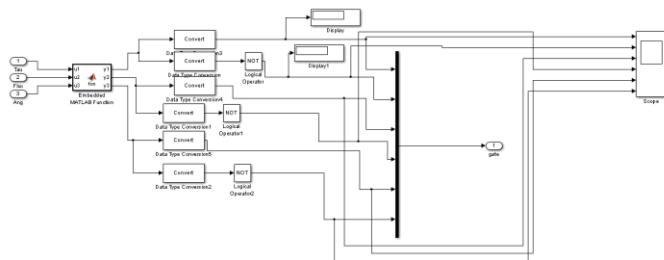


Fig -3: Gating Pulses to Inverter

### 3.6 PWM Pulses to the Inverter

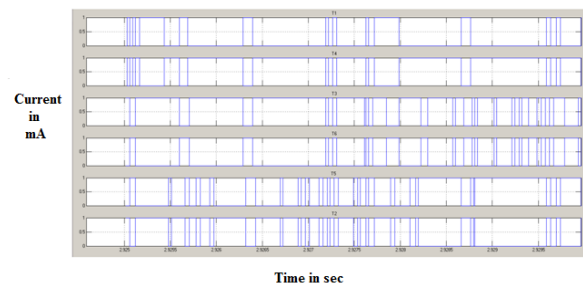


Fig -6: PWM Pulses to the Inverter

### 3.3 Clark and Park Transformation

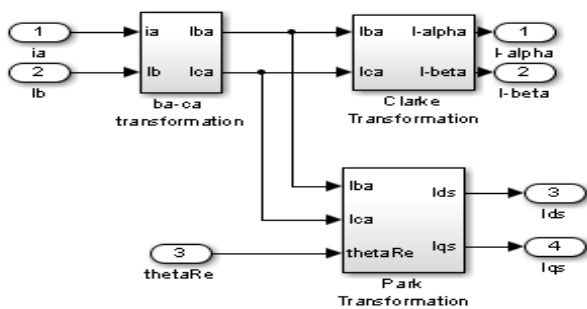


Fig -4: Clark and Park Transformation

### 3.7 BLDC Motor Back EMF Waveform

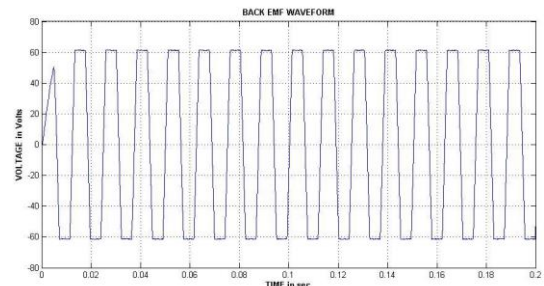


Fig -7: BLDC Motor Back EMF Waveform

### 3.4 Fuzzy Rule Table

Tab-1 Fuzzy Rule Table

$e(k)$ \ $ce(k)$	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NM	NS	NS	ZE
NM	NB	NM	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PM	PM	PM	PB
PB	ZE	PS	PS	PM	PB	PB	PB

### 3.7 BLDC Motor Stator Current Waveform

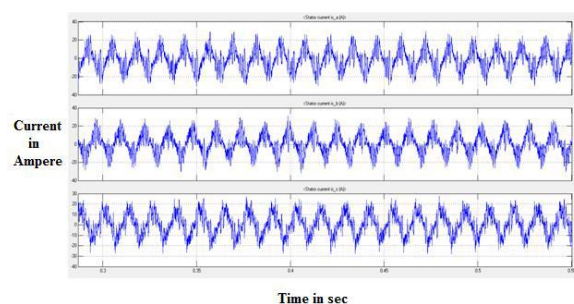
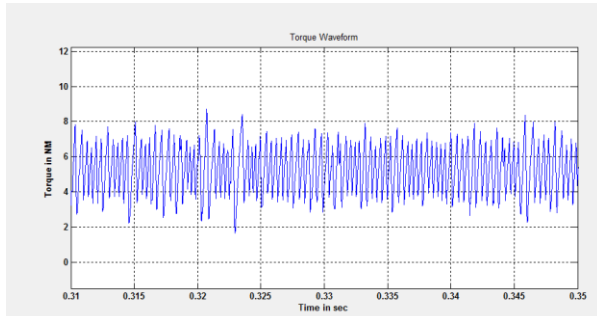


Fig -8: BLDC Motor Stator Current Waveform

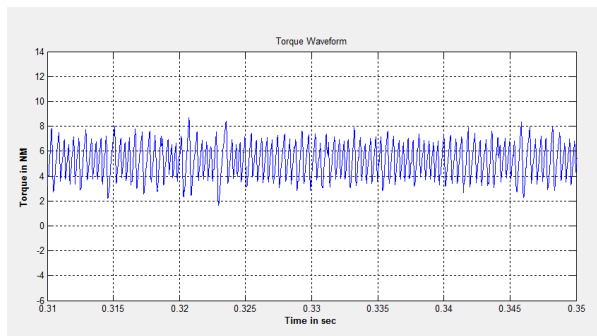
### 3.8 BLDC Motor Torque Waveform

#### (i) Without Z Source Network



**Fig -9:**BLDC Motor Torque Waveform without Z Source Network

#### (i) With Z Source Network



**Fig -10:**BLDC Motor Torque Waveform with Z Source Network

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