Modeling of ZSI based BLDCM For Reduction of Commutation Torque Ripple

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Abstract

This paper proposes a new technology, which reduces ripple context in Brush less DC Motor. This technology is having the similar modulation modes in conduction period and commutation period. In Grid applications, Brush less DC motor produces a torque ripple, hence for the reduction of ripple content, a ZSI based BLDCM is proposed in this technology. The buck-boost property of a ZSI gives a effective reduction of the ripple content and also improves the DC voltage utilization. The MATLAB/Simulink/Simpower system were selected to design and implement a ZSI based BLDCM for less torque ripple content.

Introduction

In Grid Applications we are using Brush less DC Motor because they are having simple structure, more efficiency and the maintenance cost will be very low. In BLDCM for 60degrees the stator currents changes between Incoming and outgoing phases, hence the ripple will be produced, which results that more noise and reduces the capacity of the load.[1]
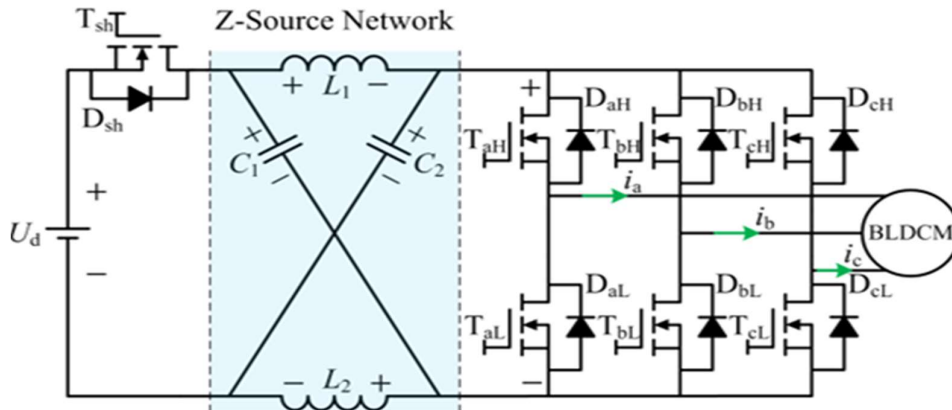

Fig. 1: BLDCM Drive System with ZSI

Fig.(1) shows the BLDCM drive system with ZSI. Here the tracking of the BLDCM is 24V and its control unit is having the supply of 5V. This drive system is having the DC Source, z-source network and s-phase bridge inverter. The ZSI is having the two identical values of capacitors that is L1=L330mH.[3] The brush less DC motor is having the Resistance and inductance with the voltage value in each phase.

ZSI Operation

The ZSI mainly operates in two states, they are shoot-through state and non–shoot-through state, here Z-source network is symmetrical because of L1=L2 and L1=L2, the voltage and current relationships are given below,

$$U_{C1}=U_{C2}=U_C$$
$$\left.\begin{array}{c} \\ uL1=uL2=uL \end{array}\right\} \dots\dots\dots\dots \quad (1)$$

$$I_{L1}=I_{L2}=I_L$$
$$\left.\begin{array}{c} \\ i_{C1}=i_{C2}=i_C \end{array}\right\} \dots\dots\dots\dots \quad (2)$$
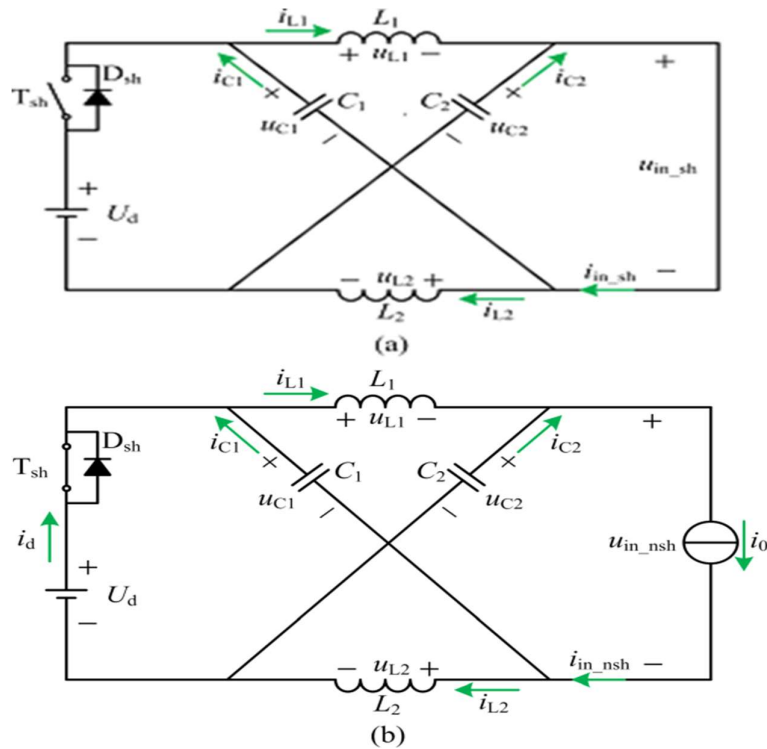
Fig. 2: Z-Source Network Equivalent Circuits

Fig.2.(a) shows the equivalent circuit of a Z-Source network in shoot-through state , from Fig.2.(a) we get

$$u_L = U_C$$
$$i_{in-sh} = 2I_L \quad \} \ldots\ldots\ldots \tag{3}$$
$$u_{in-sh} = 0$$

Fig.2.(b) shows the equivalent circuit of a Z-Source network in non-shoot-through state. In this state, the inverter bridge and brush less DC motor are equivalent to a constant current source, from Fig.2(b) we get,

$$u_L = U_C$$
$$i_{in-nsh} = i_0 \quad \} \ldots\ldots \tag{4}$$
$$u_{in-nsh} = 2U_C - U_d$$

Now the modulation period T_S is equal to the sum of the duration in shoot-through state (T_{sh}) and non-shoot-through state (T_{nsh}) and its modulation period T_S is zero. Hence we get

$$U_C T_{sh} + (U_d - U_c)T_{nsh} = 0 \quad \ldots\ldots \tag{5}$$
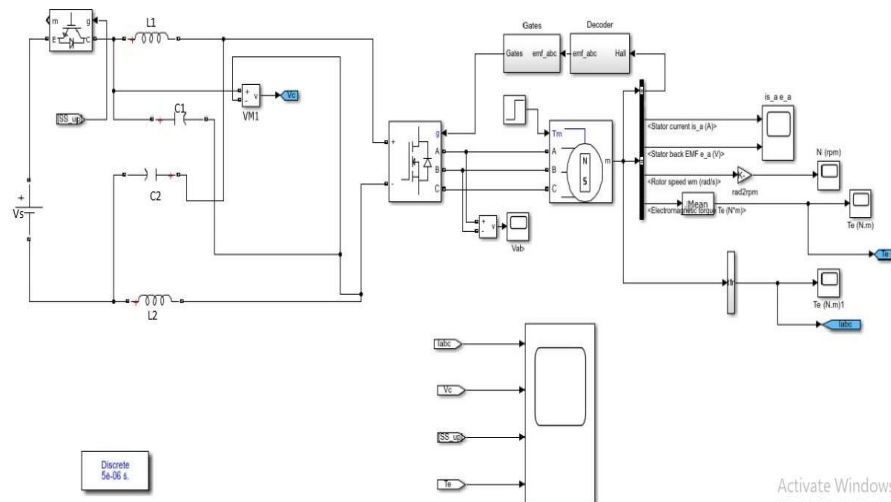
Proposed Strategy

Fig. 3: Simulink Model for ZSI based BLDCM

In this proposed system, the ripple content is observed with ZSI and with-out ZSI based brush less DC motor. Fig.3. represents simulink model for ZSI based brush less DC motor. In Fig.3.a 200W Power Rating, 24V Rated Voltage, Rated current of 14A, 4 pole brush less Dc motor and Symmetrical ZSI is built in Simulink model. [4] Here the position of brush less DC motor will be sensed by hall sensors. In Decoder, hall sensors will develops the Emf in each phase, which is shown in Fig.4.
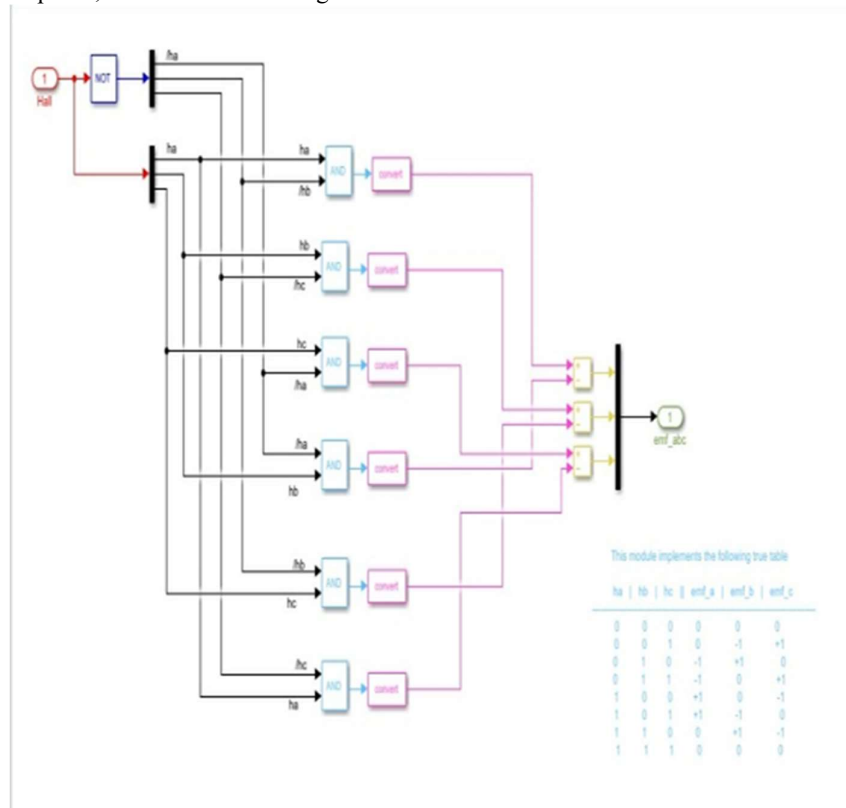

This module implements the following true table

ha	hb	hc	emf_a	emf_b	emf_c
0	0	0	0	0	0
0	0	1	0	-1	+1
0	1	0	-1	+1	0
0	1	1	-1	0	+1
1	0	0	+1	0	-1
1	0	1	+1	-1	0
1	1	0	0	+1	-1
1	1	1	0	0	0

Fig. 4: Position of Hall Effect Sensors

The emf_abc will be given to the Gate Circuit, which gives the information about the three phase bridge inverter, that is which MOSFET are going to be Turn ON in the bridge circuit, which is shown in Fig.5 & 6.
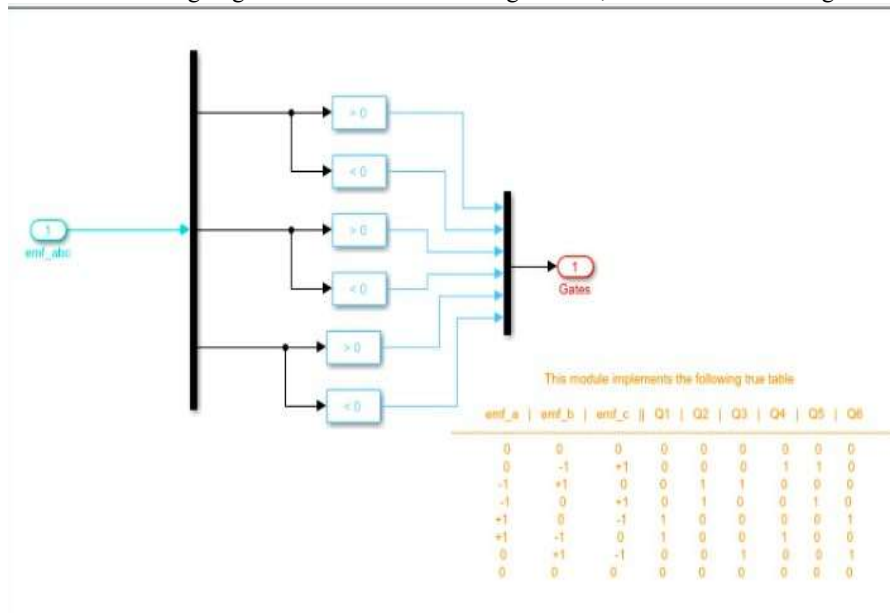

This module implements the following true table

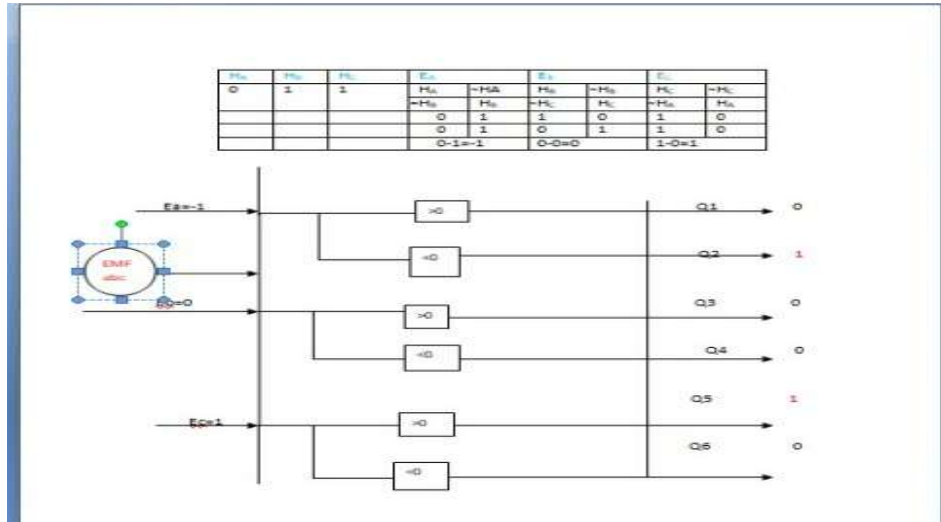| emf_a	emf_b	emf_c	Q1	Q2	Q3	Q4	Q5	Q6
0	0	0	0	0	0	0	0	0
0	-1	+1	0	0	0	1	1	0
-1	+1	0	0	1	1	0	0	0
-1	0	+1	0	1	0	0	1	0
+1	0	-1	1	0	0	0	0	1
+1	-1	0	1	0	0	1	0	0
0	+1	-1	0	0	1	0	0	1
0	0	0	0	0	0	0	0	0

Fig. 5: Gate Circuit

Fig. 6: Calculation on Emf"s

For this ZSI based brush less DC motor, the MATLAB/Simulink results for stator currents , Electro motive Force and output Torque of BLDCM is shown in Fig.7. & Fig.8. Hence from Fig.8. The ripple content with ZSI is 0.65%.
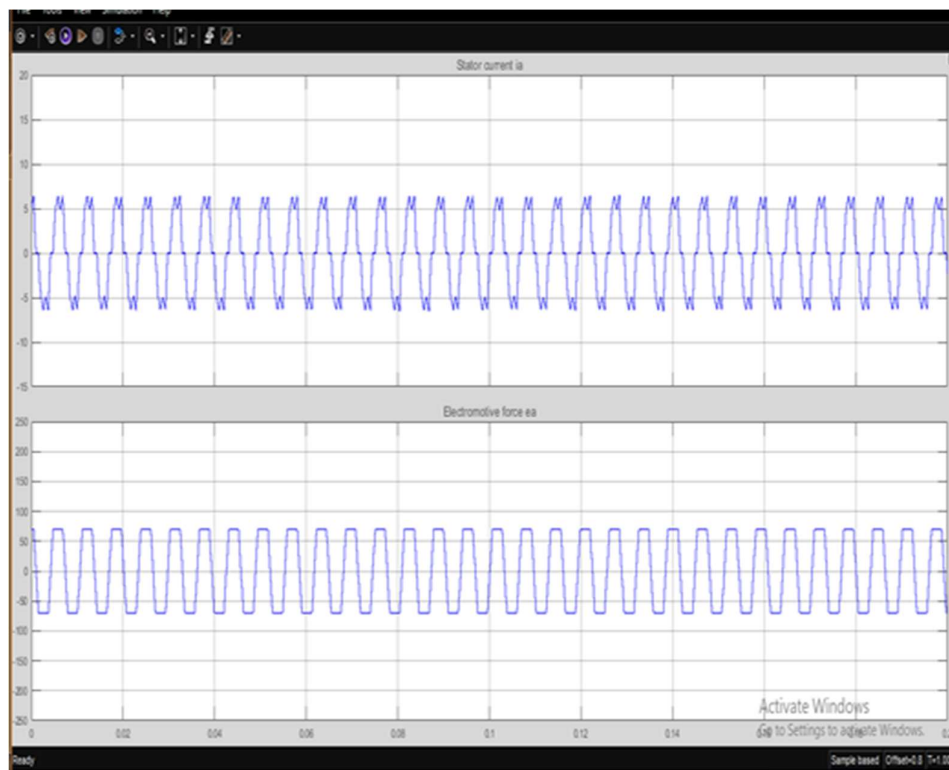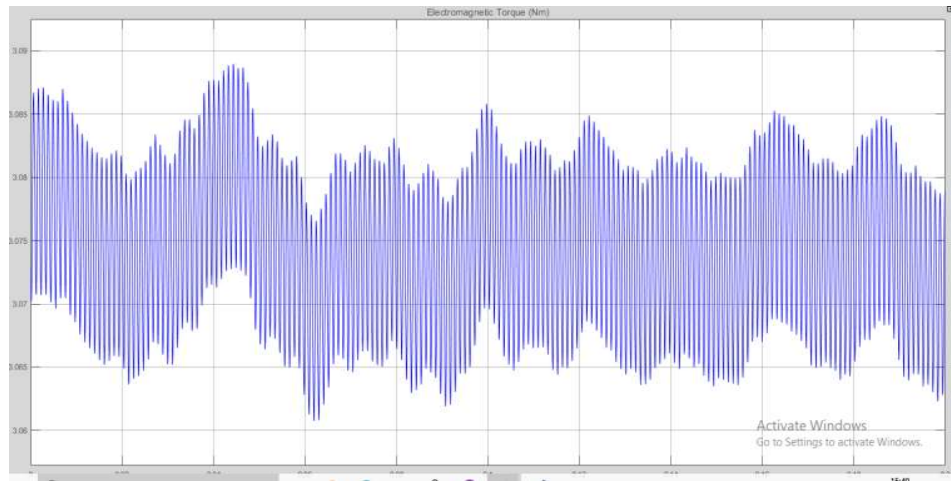

Fig. 7: Stator Currents and EMF Waveforms

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