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A NEW APPROACH FOR TORQUE RIPPLES FOR MINIMIZATION IN BLDC MOTOR

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Abstract:

In this paper, in order to optimize the dynamic performance Of the Brushless dc motor (BLDC) Speed regulation system, a nonlinear speed-control algorithm for The bldc control systems using sliding-mode control (smc) is Developed. First, a sliding-mode control method based on a new Sliding-mode reaching law (nsmrl) is proposed. This nsmrl Includes the system state variable and the power term of sliding Surface function. In particular, the power term is bounded by the Absolute value of the switching function, so that the reaching law Can be expressed in two different forms during the reaching Process. This method can not only effectively suppresses the Inherent chattering, but also increases the velocity of the system State reaching to the sliding-mode surface. Based on this new Reaching law, a sliding-mode speed controller (smsc) of pmsm Is designed. Then, considering the large chattering phenomenon Caused by high switching gain, an improved anti-disturbance Sliding-mode speed controller(adsmsc) method, called Smsc+eso method, is developed. This method introduces an Extended state observer (eso) to observe the lumped disturbance And adds a feedforward compensation item based on the Observed disturbances to the smsc. Finally, simulation and experimental Results both show the validity of the proposed control Method.

Key words – BLDC MOTOR,SEPIC converter,3-Level DCMLI,DC-bus voltage selector

I.INTRODUCTION

Brushless DC motor(BLDC) has many advantages, i.e., simple structure, high power density and high efficiency. BLDC has been widely used in the fields of high precision CNC machine tools, robot, aerospace and other fields. But at the same time, the BLDC is a complex control object with multi variable, strong coupling, nonlinear, and variable parameters. If the traditional linear control method such as proportional-integral (PI) is adopted, the control precision can only be met within a certain range. At the same time, the PI control method depends on the accuracy of the system model, which is highly susceptible to external disturbances and internal parameter changes. All these may make the control system deviating from the expected target . Therefore, in order to solve the problems of traditional PI controller, some nonlinear control theories are proposed and developed, e.g., fuzzy control, auto disturbance rejection control , predictive control , sliding-mode control (SMC) and neural network control . Among them, sliding-mode control has become a research hotspot because of its low requirement on model accuracy and strong robustness to external interference. Sliding- mode control has been successfully applied in motor speed regulation system . A fuzzy sliding-mode speed controller applied to BLDC can be found in . In , a hybrid control method based on sliding-mode controller was applied to the closed loop control system of BLDC, and the results are very conclusive regarding the effectiveness of the sliding-mode controller. In addition, a neural network sliding-mode control method was proposed in to improve speed tracking precision. However, the sliding-mode method is not flawless; indeed, in practical applications, there are time delays in switching control law, which leads to high-frequency dynamics, known as chattering. Thus, many alternative methods have been proposed to overcome the chattering phenomenon, such as reaching law method , high-order sliding-mode method , nonsingular terminal sliding-mode , and fractional-order sliding-mode . Among them, since the reaching law method can directly act on the reaching process, it can more effectively solve the chattering problem. In , a practical discrete-time fractional-order terminal sliding-mode variable structure speed controller was designed.

The experimental results show that the dynamic performance of the controlled system is improved. In , the terminal switching gain term was added on the basis of the conventional exponential approach law, and the saturation function was designed to replace the switching function. The simulation results show the effectiveness of the proposed method. added the terminal attractor on the basis of the traditional reaching law, which guarantees the system still have a fast reaching speed near the sliding-mode surface, but exists complex parameter adjusting and so on.

II.RELATED WORK

IN “T. SHI, Z. WANG AND C. XIA, "SPEED MEASUREMENT ERROR SUPPRESSION FOR PMSM CONTROL SYSTEM USING SELF-ADAPTION KALMAN OBSERVER," IN IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 62, NO. 5, PP. 2753-2763, MAY 2015.”

IN “L. SHENG, W. LI, Y. WANG, M. FAN AND X. YANG, "SENSORLESS CONTROL OF A SHEARER SHORT-RANGE CUTTING INTERIOR PERMANENT MAGNET SYNCHRONOUS MOTOR BASED ON A NEW SLIDING MODE OBSERVER," IN IEEE ACCESS, VOL. 5, PP. 18439-18450, 2017.”

IN “A. K. JUNEJO, W. XU, C. MU AND Y. LIU, "IMPROVED CONTINUOUS FAST TERMINAL SLIDING MODE CONTROL FOR SPEED REGULATION OF SUR-FACE- MOUNTED PERMANENT MAGNET SYNCHRONOUS MOTOR," 2018 21ST INTERNATIONAL CONFERENCE ON ELECTRICAL MACHINES AND SYSTEMS (ICEMS), JEJU, 2018, PP. 93-98.”

IN “S. LI AND H. GU, "FUZZY ADAPTIVE INTERNAL MODEL CONTROL SCHEMES FOR PMSM SPEED-REGULATION SYSTEM," IN IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS, VOL. 8, NO. 4, PP. 767-779, NOV. 2012”

IN “J. LI, H. P. REN AND Y. R. ZHONG, "ROBUST SPEED CONTROL OF INDUCTION MOTOR DRIVES USING FIRST-ORDER AUTO-DISTURBANCE REJECTION CONTROLLERS," IN IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL.51, NO. 1, PP. 712-720, JAN.-FEB. 2015”

IN “M. PREINDL AND S. BOLOGNANI, "MODEL PREDICTIVE DIRECT TORQUE CONTROL WITH FINITE CONTROL SET FOR PMSM DRIVE SYSTEMS, PART 1: MAXIMUMTORQUE PER AMPERE OPERATION," IN IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS, VOL. 9, NO. 4, PP. 1912-1921, NOV. 2013.”

III.MATERIALS AND METHODS

3.1 BLDC MOTOR

Brushless DC electric motor (BLDC motors, BL motors) also known as electronically commutated motors (ECMs, EC motors), or synchronous DC motors, are synchronous motors powered by DC electricity via an inverter or switching power supply which produces an AC electric current to drive each phase of the motor via a closed loop controller. The controller provides pulses of current to the motor windings that control the speed and torque of the motor.The construction of a brushless motor system is typically similar to a permanent magnet synchronous motor (PMSM), but can also be a switched reluctance motor, or an induction (asynchronous) motor.

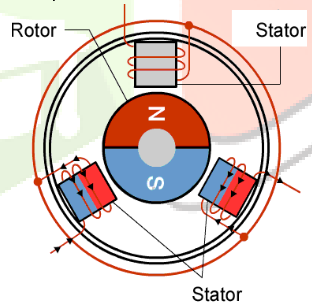

Figure 3.1 A BLDC MOTOR

3.2 CONTROL TECHNIQUES TO MINIMIZE THE TORQUE RIPPLES IN BLDC MOTOR

Various hybrid converter topologies have been proposed with a dc–dc converter to improve torque performance of two-level (2-level) inverter-fed BLDCM . A novel circuit topology with single-ended primary inductor converter (SEPIC) and a switch selection circuit has been proposed for torque ripple suppression of BLDCM drive with dc-bus voltage control. To reduce the commutation torque ripple, a voltage control strategy has been proposed to equalize the A novel circuit topology has been proposed for torque ripple suppression of the BLDCM drive system which is built by a three-level diode clamped multilevel inverter (3- level DCMLI) with two SEPICs and a commutation voltage selection circuit. In an average torque control method using one-cycle control has been proposed using dc-bus voltage and current measurements, without using back EMF and accurate rotor position information.

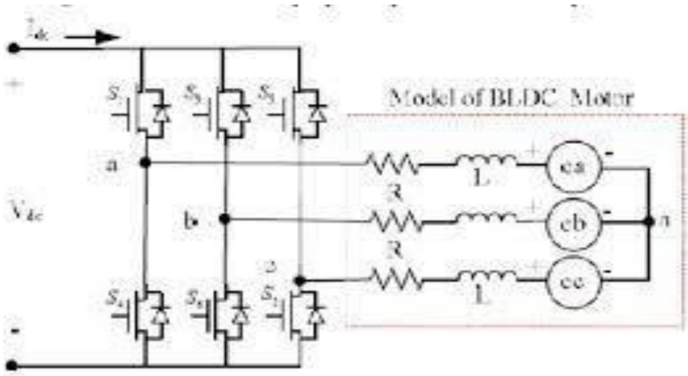

Fig.1 Schematic diagram of two level inverter fed BLDC motor

Figure 3.4.1 Schematic diagram of two level inverter fed BLDC motor

In this paper, a novel converter topology is proposed to reduce the torque ripple of the BLDCM drive system. The proposed converter is composed a modified SEPIC and a MOSFET- based 3-level DCMLI in[9]. The modified SEPIC operates with high static gain and less switching voltage stress than classical dc–dc converters. Hence, the modified SEPIC is used in this proposed torque ripple suppression circuit and the duty cycle is adjusted to obtain the desired dc-bus voltage based on the spinning speed of the BLDCM. The 3-level DCMLI is used for further reduction of the current ripple and as well as the resultant torque ripple. The MOSFET-based voltage selector circuit is used to apply regulated dc-bus voltage for efficient commutation torque ripple suppression. Simulation and experimental results show that the proposed converter topology with the dc-bus voltage selector circuit significantly reduces the torque ripple during the commutation interval.

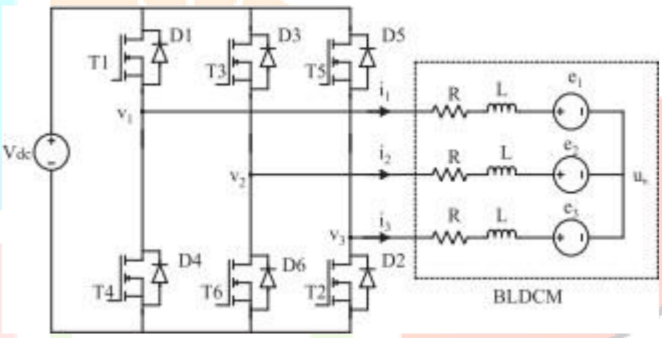

Figure 3.4.2. Equivalent model of 2-level inverter-fed BLDCM

3.3 SINGLE –ENDED PRIMARY-INDUCTOR CONVERTER (SEPIC)

The single-ended primary-inductor converter (SEPIC) is a type of DC/DC converter that allows the electrical potential (voltage) at its output to be greater than, less than, or equal to that at it s input. The output of the SEPIC is controlled by the duty cycle of the control transistor.

A SEPIC is essentially a boost converter followed by a buck-boost converter, therefore it is similar to a traditional buck-boost converter, but has advantages of having non-inverted output (the output has the same voltage polarity as the input), using a series capacitor to couple energy from the input to the output (and thus can respond more gracefully to a short-circuit output), and being capable of true shutdown: when the switch is turned off, its output drops to 0 V, following a fairly hefty transient dump of charge. SEPICs are useful in applications in which a battery voltage can be above and below that of the regulator's intended output. For example, a single lithium ion battery typically discharges from 4.2 volts to 3 volts; if other components require 3.3 volts, then the SEPIC would be effective.

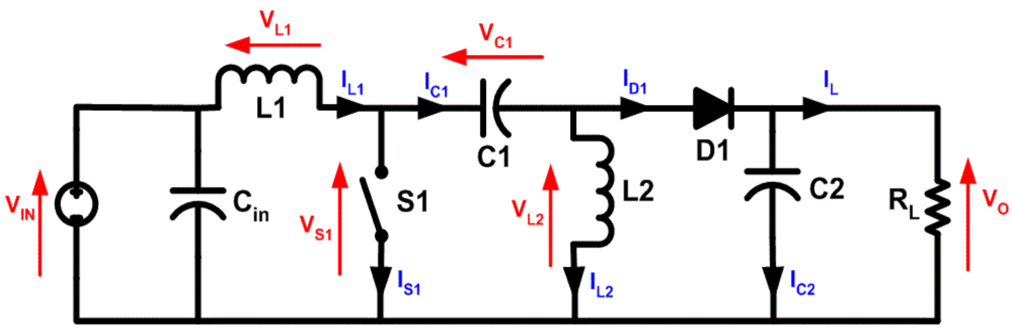

Figure 3.3: Schematic of SEPIC

3.4 INVERTER

An inverter is an electrical device that converts direct current (DC) to alternating current (AC) the converted AC can be at any required voltage and frequency with the use of appropriate transformers, switching, and control circuits. Static inverters have no moving parts and are used in a wide range of applications, from small switching power supplies in computers, to large electric utility high voltage direct current applications that transport bulk power[11]. Inverters are commonly used to supply AC power from DC sources such as solar panels or batteries. The electrical inverter is a high power electronic oscillator. It is so named because early mechanical AC to DC converters were made to work in reverc Figure 5.2 : Single-phase structure of a multilevel cascaded H-bridges inverter

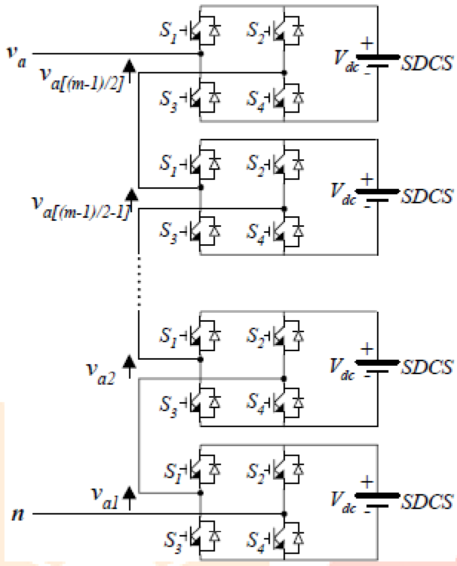

Figure 5.2 : Single-phase structure of a multilevel cascaded H-bridges inverter

A single phase structure of an m-level cascaded inverter is illustrated in Figure 16. Each separate DC source (SDCS) is connected to a single phase full bridge, or H-bridge, inverter. Each inverter level can generate three different voltage outputs, $+V_{dc}$, 0, and $-V_{dc}$ by connecting the DC source to the ac output by different combinations of the four switches, S_1, S_2, S_3, and S_4. To obtain $+V_{dc}$, switches S_1 and S_4 are turned on, whereas $-V_{dc}$ can be obtained by turning on switches S_2 and S_3. By turning on S_1 and S_2 or S_3 and S_4, the output voltage is 0. The AC outputs of each of the different full bridge inverter levels are connected in series such that the synthesized voltage waveform is the sum of the inverter outputs.

The number of output phase voltage levels m in a cascade inverter is defined by m = 2s+1, where s is the number of separate DC sources. An example phase voltage waveform for an 11 level cascaded H-bridge inverter with 5 SDCSs and 5 full bridges is shown in Figure 5.2

IV.PROPOSED CONCEPT

A system diagram of a proposed new converter topology for the BLDCM drive system based on a 3-level DCMLI and a modified SEPIC is shown in Fig. 4. In this topology, the 3- level DCMLI is proposed to reduce current ripple, and modified SEPIC is included to adjust thedc-bus voltage based on the rotational speed of the BLDCM. The dc-bus voltage selector circuit is constructed with power MOSFETs (S1, S2, S3, and S4)[12]. It is used to select the desired dc-bus voltage for signifi- cant torque ripple reduction during commutation interval.

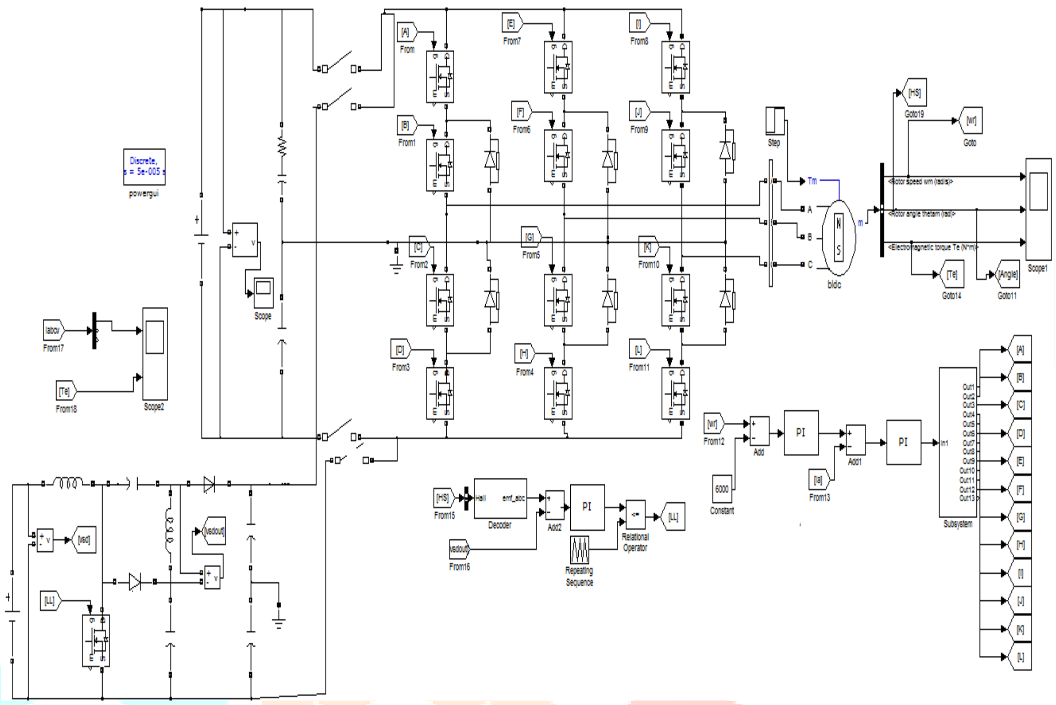

Figure 4 BLDCM fed by proposed topology

The MOSFET-based 3-level DCMLI is operated at a switching of 80 kHz, which provides significant torque ripple suppression than the conventional 2-level inverter. In this 3-level DCMLI, the dc-bus voltage is divided into 3 levels by the capacitors C5 and C6. To obtain the desired commutation voltage, the duty cycle of the modified SEPIC can be adjusted during the non commutation period to maintain Vdc = 8Em . At the start of commutation period, the regulated voltage from the modified SEPIC is instantly applied by voltage selector circuit for significant torque ripple suppression.
The commutation path of three-level DCMLI leg A is depicted in Fig. 4. The following modes of operation of the 3-level DCMLI are discussed based on the polarity of the voltage at the inverter output terminals and direction of the load current.

V.SIMULATION RESULTS

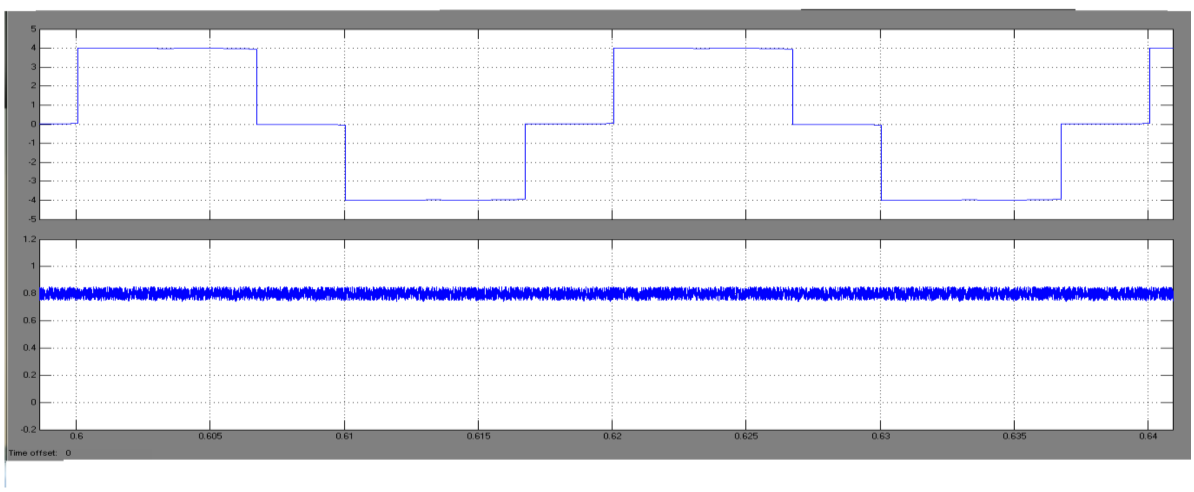

Figure5.1.Current and torque waveforms of 3 BLDCM fed by proposed topology at 1000 r/min and 0.825Nm with 5 kHz switching frequency.

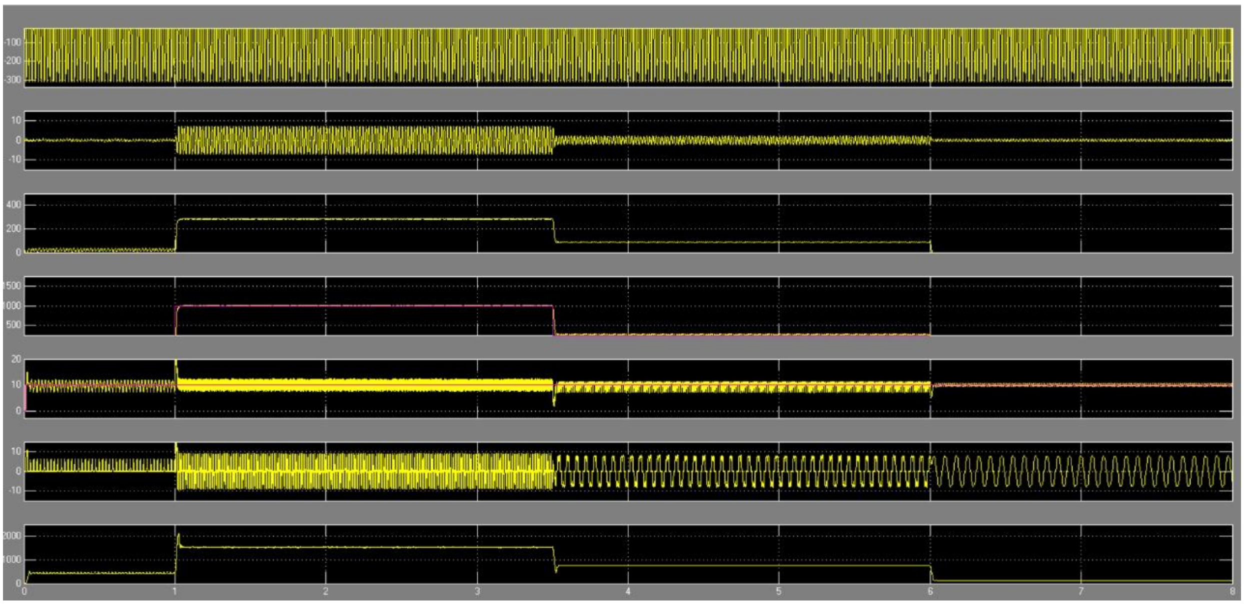

Figure 5.2 Simulation result of Repeating sequence

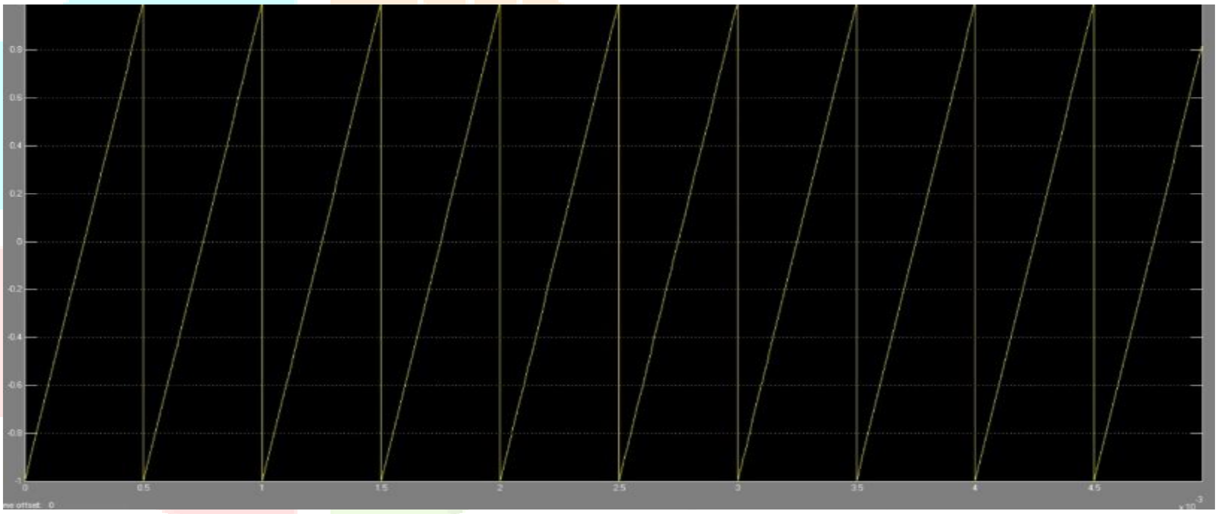

Figure 5.3: Simulation result of a) Vss b) Iss c) Vdc d) Speed e) torque f) 3-Phase Current g) Mean value

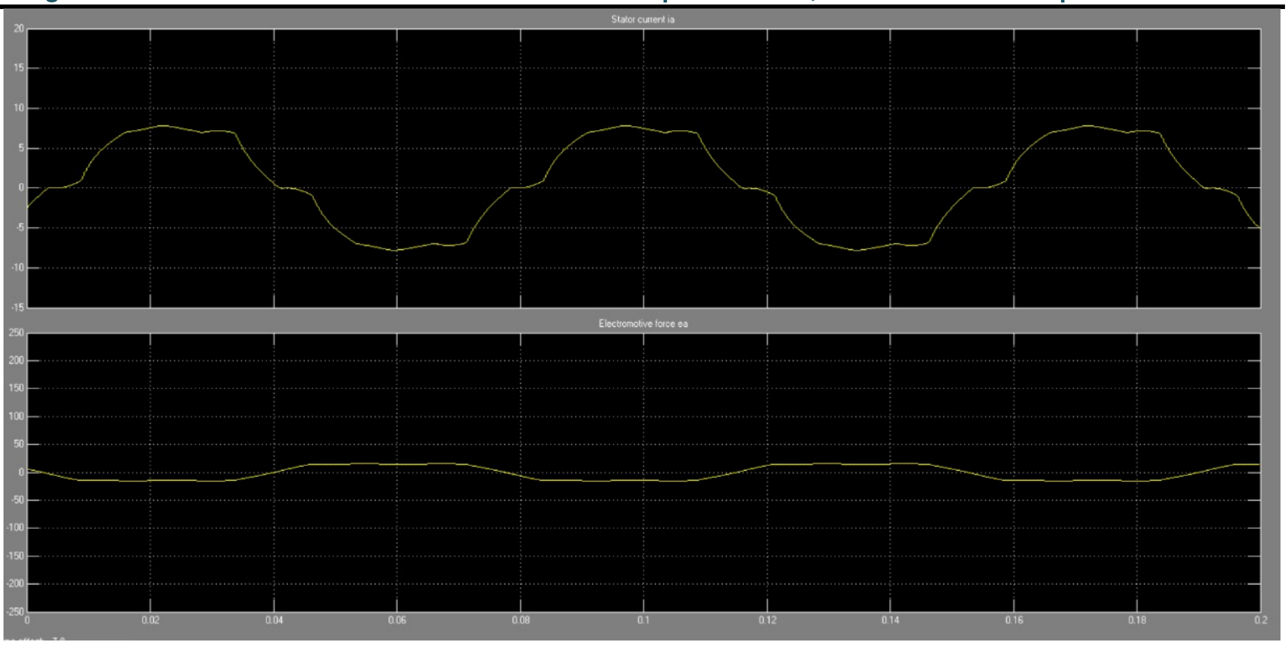

Figure 5.4: Simulation result of a) stator current b) stator Back EMF

VI.CONCLUSION

In this project, a commutation torque ripple reduction circuit has been proposed using 3-level DCMLI with modified SEPIC and a dc-bus voltage selector circuit. The suggested dc-busvoltage control strategy is more effective in torque ripple reduction in the commutation interval. The proposed topology accomplishes the successful reduction of torque ripple in the commutation period and results are presented to compare the performance of the proposed control technique with the conventional 2-level inverter, 3-level DCMLI, 2-level inverter with SEPIC and the switch selection circuit-fed BLDCM. In order to obtain significant torque ripple suppression, quietness, and higher efficiency, 3-level DCMLI with modified SEPIC and the voltage selector circuit is the most suitable choice to obtain high-performance operation of BLDCM. The proposed topology may be used for the torque ripple suppression of BLDCM with the very low stator winding inductance. The results of the prediction are evaluated by a cost function (known also as quality or decision function) , which provides the criterion for choosing the appropriate control action. Due to the cost function, MPC can handle non-linear systems, multiple input and multiple output (MIMO) systems, and system constraints in an unified manner, which makes it fairly unique and which is appreciated by many scientists .

VII.FUTURE SCOPE

Compared with STA-SMC, NSTA-SMC with adaptive term effectively solves the problem of low reaching speed and poor anti disturbance ability caused by the square root calculation of proportional term in the original super twisting algorithm without increasing system chattering and improves the dynamic following performance of the system.

Compared with the SMC based on the exponential reaching law, the NSTA-SMC effectively solves the contradictory problems between sliding mode chattering and reaching speed and anti disturbance ability under the premise of suppressing chattering and further improving the system control quality.

Compared with PI, NSTA-SMC effectively improves the PI control excessive overshoot and poor anti disturbance ability and improves the dynamic and static quality of the system.

At the same time, how to ensure the optimal sliding mode gain of the new super twisting algorithm has become the research focus to further improve the system performance.

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