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# Speed Control of BLDC Motor Using CUK Converter

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**ABSTRACT:** The BLDCM are widely used in the low power application of servo motor due to their different advantages over conventional DC motors, induction motor and permanent magnet motor. However high performance motor require fast and accurate speed control of the system, quick revival of speed from any disturbance and sensitivity to motor parameter variation. To operate the motor with proper reference speed different controllers are widely used in industrial application. In this present work, a Cuk converter is designed with adaptive neuro based fuzzy PID controller is used to tune the PID controller parameters for speed control of BLDC motor. Ziegler- Nicholas tuning formula is used for tuning and gain predication of adaptive neuro fuzzy controller. Genetic algorithm is a strong optimization technique based on natural selection by considering the different parameters such as rise time settling time and overshoot of the response. Simulation results are obtained from different conventional controllers as well fuzzy-PID controller are compared with the adaptive neuro fuzzy PID controllers.

**KEYWORDS**: BLDCM, CUK Converter, Adaptive Neuro Fuzzy Interface System-PID(ANFIS-PID).

## I. INTRODUCTION

RUSHLESS DC (BLDC) motors are recommended for many low and medium power drives applications because of their high efficiency, high flux density per unit volume,
low maintenance requirement, low EMI problems, high ruggedness and a wide range of speed control [1, 2]. Due to these advantages, they find applications in numerous areas
such as household application [3], transportation (hybrid vehicle) [4], aerospace [5], heating, ventilation and air conditioning (HVAC) [6], motion control and robotics [7],
renewable energy applications [8, 9] etc. The BLDC motor is a three phase synchronous motor consisting of a stator having a three phase concentrated windings and a rotor having permanent magnets [10, 11]. It doesn't have mechanical brushes and commutator assembly, hence wear and tear of the brushes and sparking issues as in case of conventional DC machines are eliminated in BLDC motor and thus has low EMI problems. This motor is also referred as electronically commutated motor (ECM) since an electronic commutation based on the Hall-Effect rotor position signals is used rather than a mechanical commutation [12, 13].

## II. SYSTEM CONFIGURATION

Figs. 1 show the PFC Cuk converter based VSI fed BLDC motor drive using a current multiplier and a voltage follower approach respectively. A high frequency metal oxide semiconductor field effect transistor (MOSFET) is used in Cuk converter for PFC and voltage control [14-17], whereas insulated gate bipolar transistor's (IGBT) are used in the VSI

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for its low frequency operation. BLDC motor is commutated electronically to operate the IGBT's of VSI in fundamental frequency switching mode to reduce its switching losses. The PFC Cuk converter operating in CCM using a current multiplier approach is shown in Fig. 1; i.e. the current flowing in the input and output inductors (Li and Lo), and the voltage across the intermediate capacitor (C1) remain continuous in a switching period. Whereas, Fig. 2 shows a Cuk converter fed BLDC motor drive operating in DCM using a voltage follower approach. The current flowing in either of the input or output inductor (Li and Lo) or the voltage across the intermediate capacitor (C1) become discontinuous in a switching period [18, 19] for a PFC Cuk converter operating in DCM. A Cuk onverter is designed to operate in all three discontinuous conduction modes and a continuous conduction mode of operation and its performance is evaluated for a wide voltage control with unity power factor at AC mains.

Conventional schemes of PFC converters fed BLDC motor drive utilize an approach of constant DC link voltage of the VSI and controlling the speed by controlling the duty ratio of high frequency pulse width modulation (PWM) signals [22- 25]. The losses of VSI in such type of configuration are considerable since switching losses depend on the square of switching frequency (Psw_loss α fS2). Ozturk et. al. [22] have proposed a boost PFC converter based direct torque controlled (DTC) BLDC motor drive. They have the disadvantages of
using a complex control which requires large amount of sensors and higher end digital signal processor (DSP) for attaining a DTC operation with PFC at AC mains.

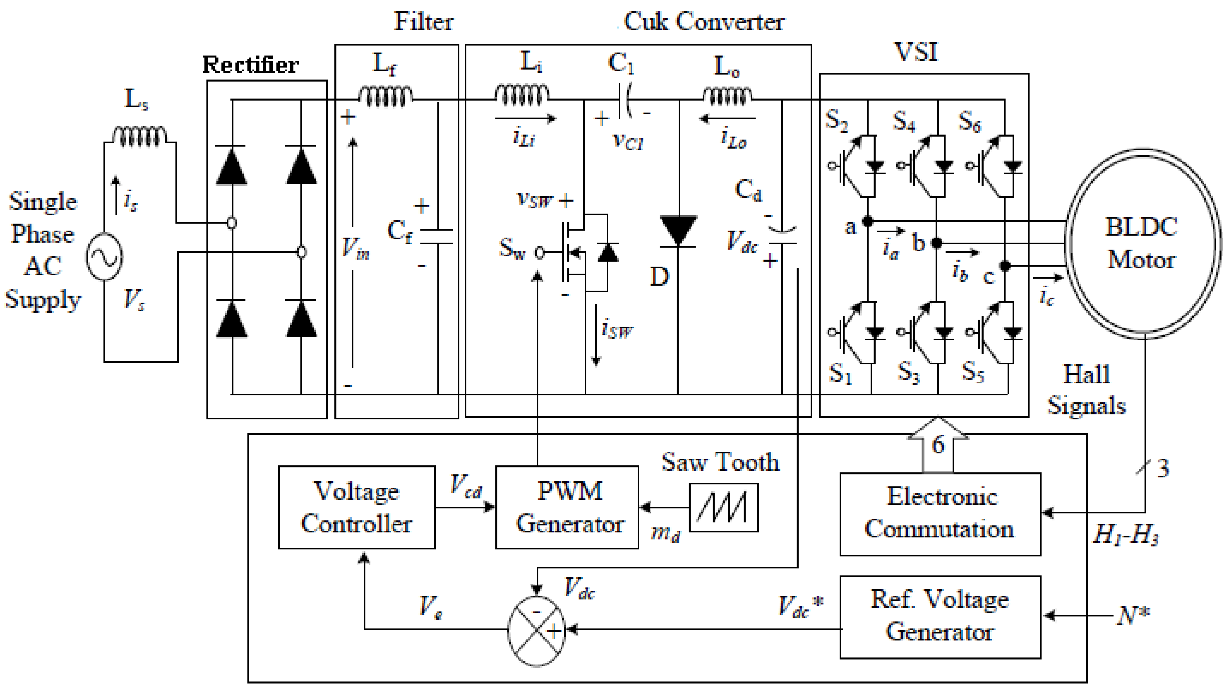


Fig. 1 A BLDC motor drive fed by a PFC Cuk converter using a voltage follower approach.

### A. *Control of BLDC Motor: Electronic Commutation*

The conduction states of two switches ($S1$ and $S4$) are shown in Fig. 2. A line current $i_{ab}$ is drawn from the direct current link capacitor whose magnitude depends on the applied direct current link voltage ($V$dc), back electromotive forces ($e$an and $e$bn), stator resistances ($Ra$ and $Rb$), and self-inductance and mutual inductance ($L_a$, $L_b$, and M) of the stator windings. Table I shows the specification of BLDC motor for different switching states of the voltage source inverter (VSI) feeding a BLDC motor based on the Hall-effect position signals ($Ha$ ,$H_b$ & $Hc$)[20].

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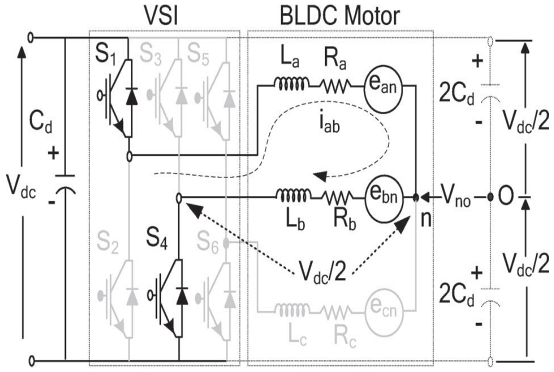
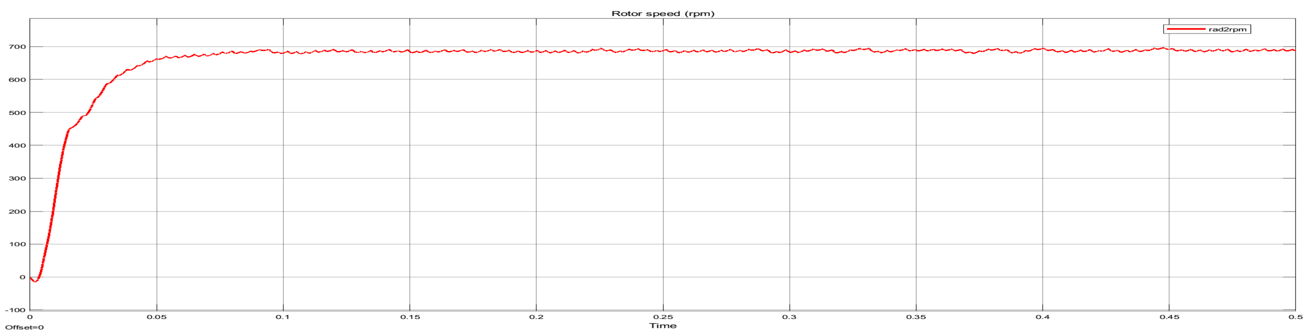



Fig. 2. Operation of a Voltage Source Inverter -fed BLDC motor when switches *S*1 and *S*4 are conducting

| TABLE I SPECIFICATIONS OF BLDC MOTOR | |
|---|---|
| PARAMETERS | RATINGS |
| Voltage in volts | 24 V |
| Current in Amps | 8.5A |
| Power in Watts | 250W |
| Speed in rpm | 300 |
| Resistance in ohms | 0.2Ω |
| Rated Torque (Trated) | 2.3 N.m |
| Number of Poles | 3 |
| Phase Inductance in Hentry | 0.3mH |
| Moment of Inertia (J) | 4.1g.m$^2$ |

## III. SPEED CONTROL OF BLDC MOTOR

The performance characteristics of BLDC motor drive with conventional controller as well as combination of intelligent controllers have been investigated such as fuzzy PID[21].Figure 3-5 shows the simulation diagram cuk converter using adaptive neuro fuzzy PID controller. Table II shows the analysis of four different load configurations of the BLDC motor drive. The evaluation is based on settling time, rise time and peak overshoot of closed loop ANFIS PID controller implemented in BLDC motor drive.



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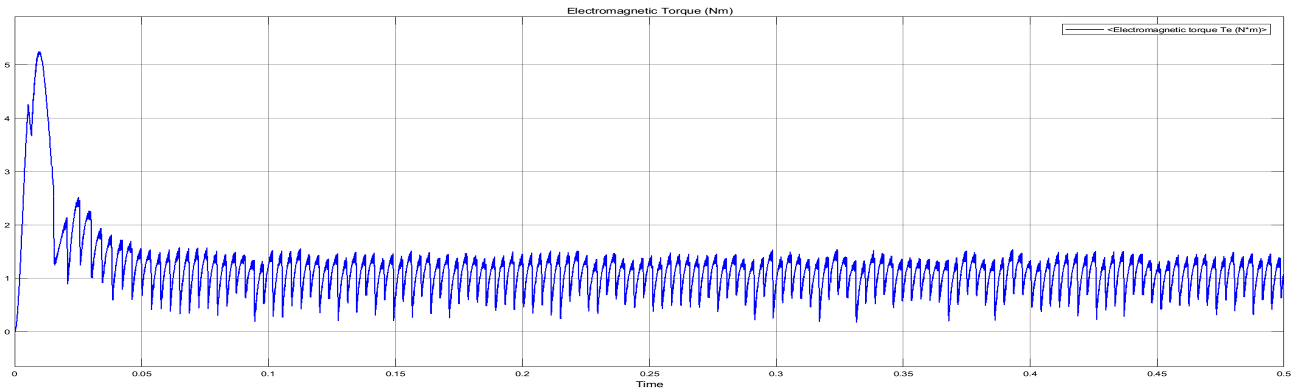


Fig. 3 (a) & (b) Speed & Torque Characteristics of BLDCM using converter

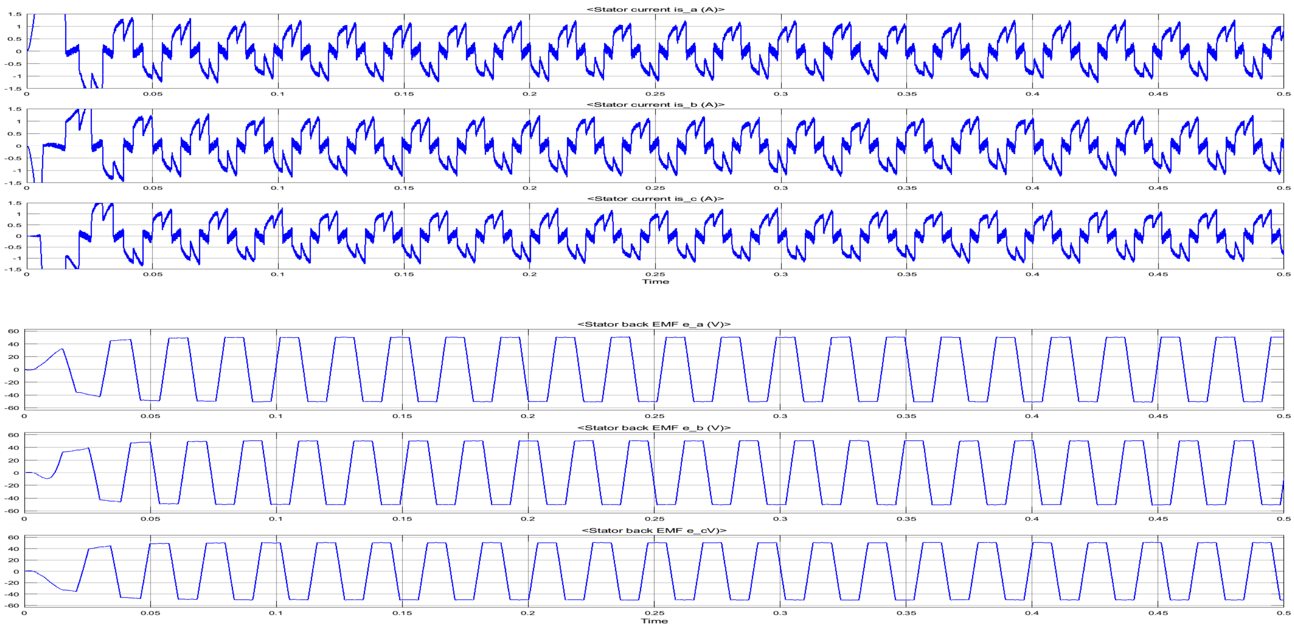


Fig. 4 (a) & (b) Stator current & stator EMF Characteristics of BLDCM using Cuk converter

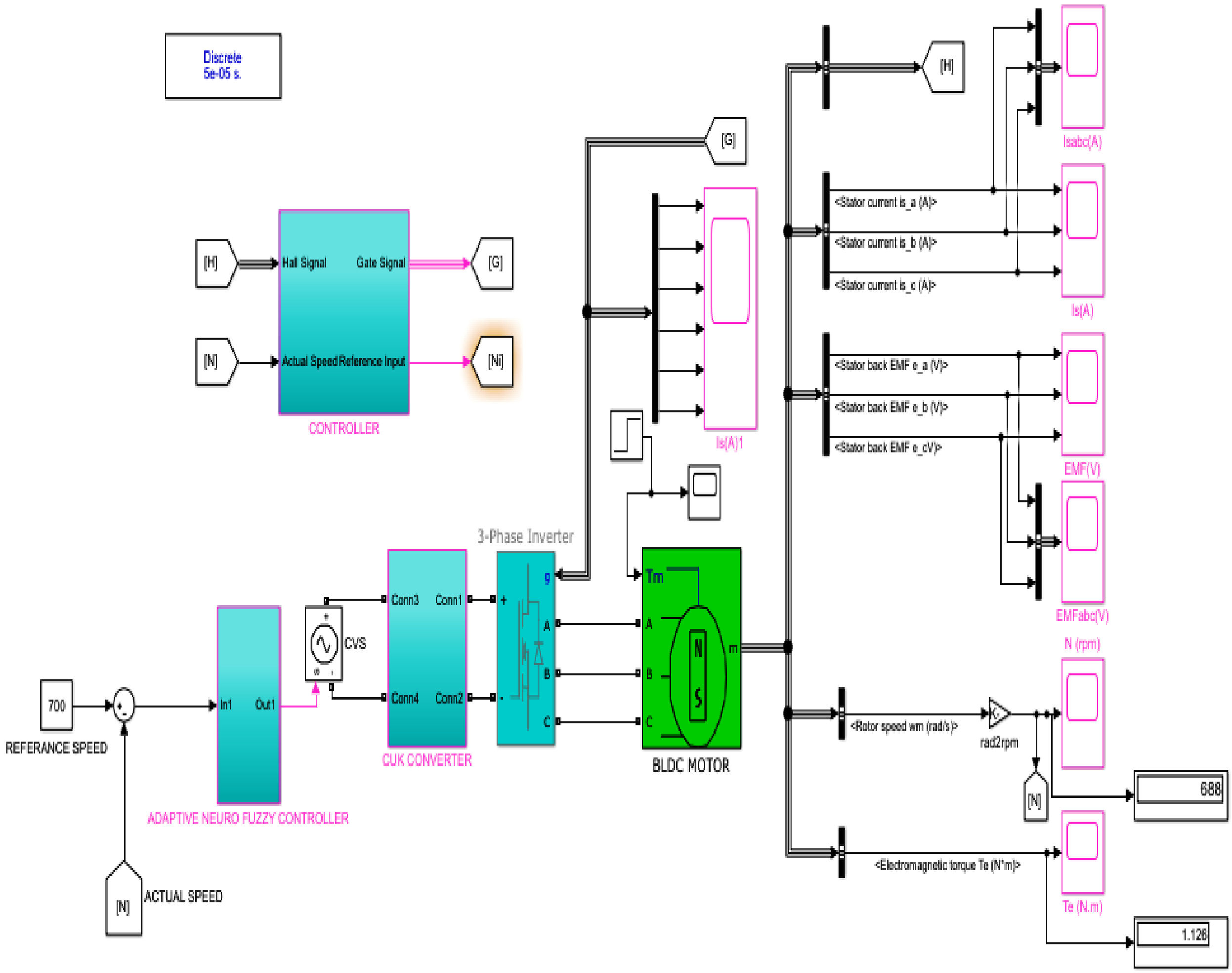


Fig 5 (a) & (b) Overall simulation diagram of BLDCM using Cuk converter

Table II. Performance parameters values with designed ANFIS PID controller using cuk converter

| Different Load | Actual Speed (rpm) | Torque (Nm) | Time Period(sec) | Rising Time(sec) | Settling Time(sec) | Overshoot | Error Speed (rpm) |
|---|---|---|---|---|---|---|---|
| **No Load** | 700 | 0.1211 | 1 sec | 31.791ms(0.031791s) | 6.999ms(0.06791s) | 0.681% | **0** |
| **50% of Load** | 700 | 1.484 | 1 sec | 30.025ms(0.03025s) | 6.074ms(0.006074s) | 0.735% | **0** |
| **75% of Load** | 700 | 1.476 | 1 sec | | | | **0** |
| **Full Load** | 700 | 1.48 | 1 sec | | | | **0** |

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## IV. CONCLUSION

A Cuk converter for Voltage Source Inverter fed BLDC motor drive has been designed for controlling the low speed of motor using adaptive nuero fuzzy PID controller achieving a low rise time, settling and peak overshoot time for the development of low cost BLDC motor for numerous low power equipments such fans, blowers, water pumps etc. The speed of the motor drive has been controlled by varying the DC link voltage of VSI; which allows the voltage source inverter to operate in fundamental frequency switching mode for reduced switching losses.

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