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BLDC motor based CUK converter using model predictive controller for low power applications

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ABSTRACT

In this paper, a power converter CUK based a Brushless DC motor (BLDC) is designed by the model predictive controller for low power applications. The BLDC motor drive speed is controlled by maintaining of DC link capacitor and controlled gate signals of inverter. It uses low switching frequency of source inverter for less switching losses. The sensor less based motor speed is controlled by using model predictive controller with transformation technique. CUK converter combined with the Fuzzy Logic Controller (FLC) to attain the high voltage gain in discontinuous mode to control the capacitor which holding the dc link voltage. FLC with the CUK converter is operated in two operating conditions of continuous and discontinuous modes. The proposed system is designed in MATLAB/Simulink

Key words : BLDC drive, CUK converter, Fuzzy Logic Controller, Model Predictive Controller

1. INTRODUCTION

Brushless DC motor has wide range of merits such as high efficiency, high torque, speed control, are makes the drive an ideal in many applications. It consists of stator and rotor. In [1-2] the stator a concentrated three phase winding is and a permanent magnet in rotor. In this drive an electronic commutation is done by inverter based on position of rotor sensed using Hall Effect sensors signals [3-4]. This motor doesn't have any brushes and no more the sparking problem because of this it has low EMI [5]. The main applications of the BLDC motor are; household appliances, heating, industrial drives, aerospace, transportation and automation field [6-8].

BLDC drive is supplied through rectifier and dc link capacitor which in high value and a small amount of current supplies for short extent as the instant dc link capacitor value is lesser than of applied voltage [9]. There is a power quality improvement is required to reduce the harmonic distortion (THD) at AC source while peak current [10]. In case of conventional method the harmonics about 60-70% which caused to poor power factor of the system at AC and value of PF is 0.6-0.7[11]. The cost of the such drives are high due to the sensors such as current sensors are required to pulse width modulation depends on speed control in drives.[12]. To attain unity power factor the converters of single phase power factor correction are used and it has reduced losses on switching components [13-14]. The conventional system has single ended primary inductance converter (SEPIC) for correction of power factor but uses VSI based pulse width modulation that has more losses in switching devices and the cost is high due to requirement of more active and passive elements [15]. Normally the controllers are used in drives are to control the process of the system and provide efficient gate signals for bridge networks. The fuzzy controller is a rules based and to provide best values from the constant change. The model predictive controller is used in several applications ranges from simple system to complex one.

Moreover, high numbers of sensors are required to control BLDC motor speed due to switches with high frequency. A buck and boost converter used to correct the power factor and maintains dc link voltage but it has low boost factor. The proposed CUK converter is simple to design and using single gate driver which triggering the two switches at same time and operating in four control modes.

1.1 Proposed System

Proposed system consist a CUK converter combined with BLDC motor. The BLDC motor is fed using VSI. VSI contains six metal oxide semiconductor field effect transistors (MOSFET) for its process at low frequency. The metal oxide semiconductor field effect transistor (MOSFET) semiconductor device with high frequency can be used in CUK converter with fuzzy logic control (FLC) scheme. Pulse width modulation signals of low duty ratio with high frequency are controlled for controlling the speed of motor. A diode rectifier is done the process of rectification. BLDC drive is commutated electronically and reduces its switching losses in fundamental frequency of VSI. The converter operation in current continuous mode (CCM) using control is shown in figure 1. The input and output inductors are namely L1 and Lf conducting current and the potential remains in CCM switching duration across the capacitor. In voltage control the L1 or Lf becoming a discontinuous switching period. The BLDC drive fed CUK converter using in discontinuous conduction mode shows in figure 1. The performance of continuous and discontinuous mode is evaluated for unity power factor at ac source and voltage control..

1.2 Operation

Proposed system operating in four modes as follows
1. A continuous conduction mode
2. Three modes in discontinuous conduction mode

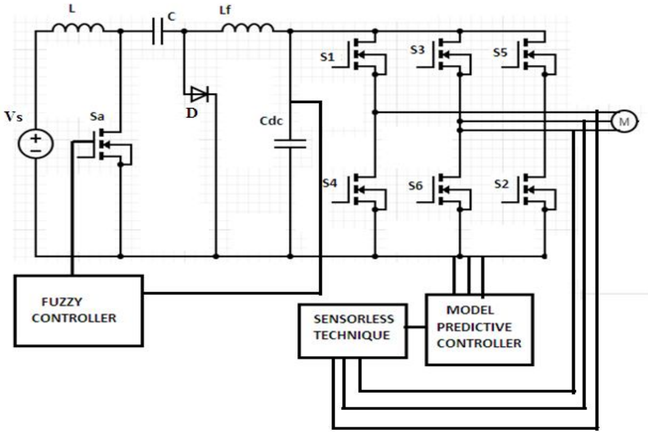

Figure 1: proposed system circuit diagram

CCM

The CUK converter is operating in two various intervals. In interval 1 switch S1 is ON and L is storing energy then capacitor discharges power to dc link capacitor through this the voltage is maintained. In interval 2 switches S in off state, stored power in L supplied to capacitor which maintaining dc voltage and C1is energized from the stored power in L.

DCM: I

This mode, CUK converter is operating with two various intervals. In the first interval, as S in ON state the inductor is storing the power and C discharges the energy through S to DC voltage maintaining capacitor. Through D, the stored energy in L is transferring to C as Switch S is OFF state.

DCM: II

This mode, as the S in active state, L is storing the power and dc link capacitor is charged by capacitor via switch S. In interval two, when the S is off state, then stored power in the L is applied to capacitor that act as intermediate.

DCM: III

In this mode, at first interval, when switch S in turned on state, the inductor L is storing the power and through S switch, the Dc link capacitor is charged by C. In interval, the capacitor is completely discharged while S in active state.

2. CONTROLLERS

2.1 Model Predictive Control (MPC)

In this system, two controllers are used. The model predictive controller is using a system dynamic model to predict the system desires response in future. The utilization of MPC can be reduced the cost function performance. Model predictive controller is used to provide pulses to three phase inverter. The inverter supply is fed to the brushless DC motor and speed is controlled. Figure 2 shows the proposed model predictive controller.

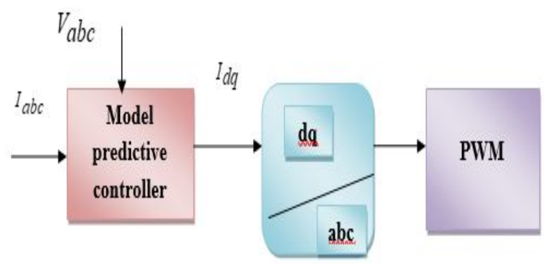

Figure 2: Model predictive controller

2.2 Fuzzy Logic Controller

Fuzzy logic controller is controlling the gate signal that provide to power converter switch control. The efficient result can be obtained using rules and to achieve the set point when comparing with conventional type of controllers. Through this controller, CUK converter voltage gain is achieved. The following figure 3 shows the proposed fuzzy logic controller. The fuzzy logic controller has three steps: fuzzy, rules execution and defuzzification. In the fuzzification process the constantly changing values are converted into variables of fuzzy. The fuzzy variables are processed based on 3*3 rules and they are actually experienced. If and then conditions are used. Finally the defuzzification is proceeding in which the output variable is obtained.

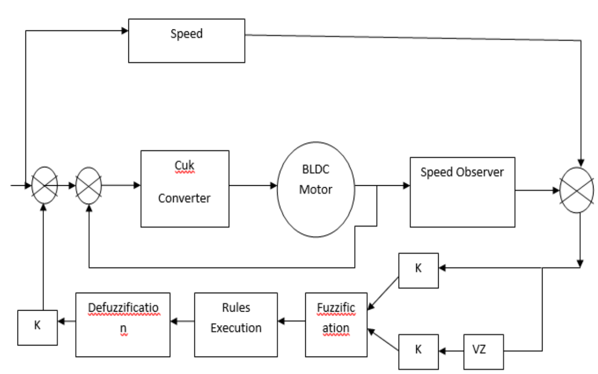

Figure 3: Fuzzy Logic Controller

2.3 Simulation and Result

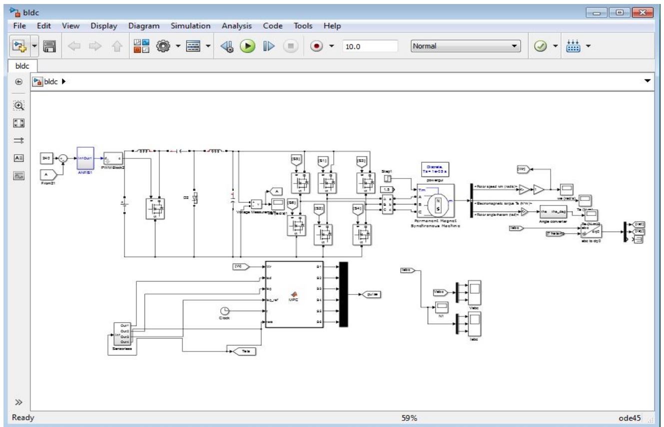

Figure 4: Proposed system Simulink model

The input DC voltage is 60v as shown in figure 5 and the dc link voltage of the given system is shown in figure 6.

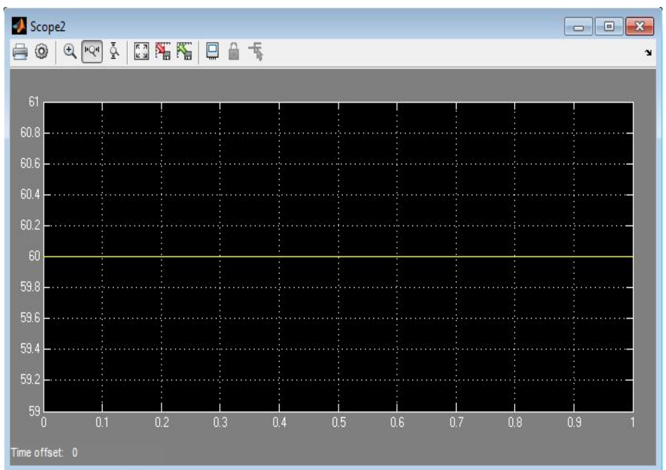

Figure 5: Input DC voltage

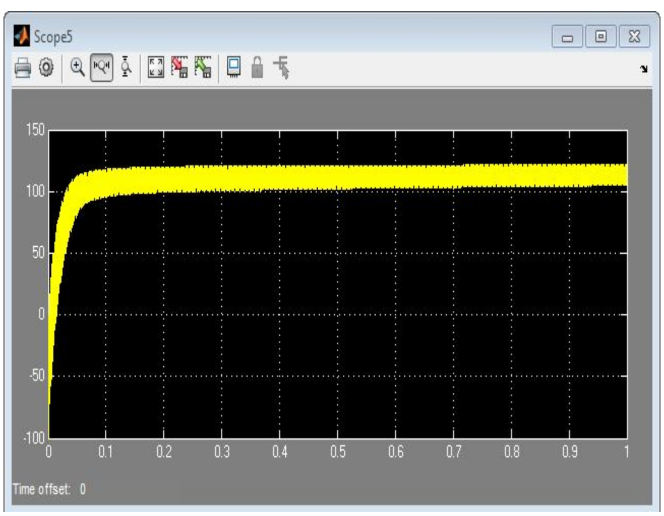

Figure 6: DC link voltage

The stator current of the proposed system is shown in figure 7.

Figure 7: Stator current outputs

The speed of the motor is shown in figure 8 controlled using model predictive controller. The achieved speed is 600 rpm.

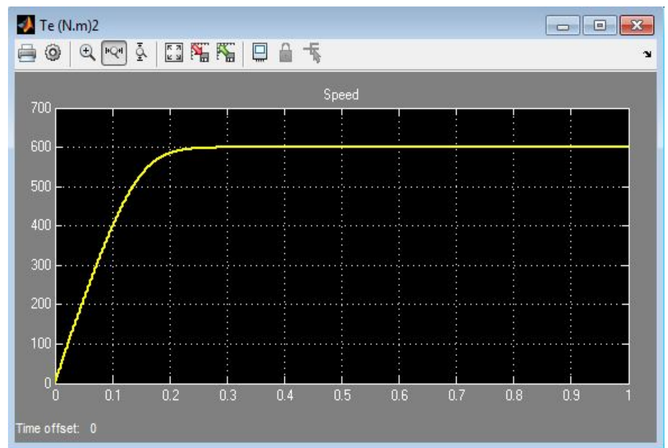

Figure 8: Proposed system speed

The output BLDC motor torque shows in figure 9.

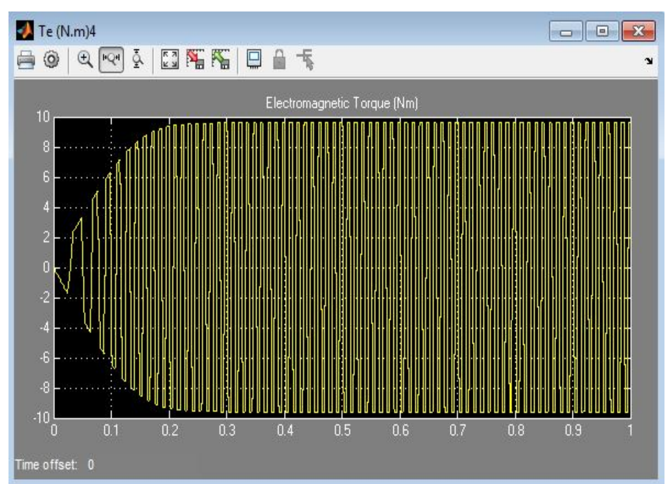

Figure 9 : Output Torque

5. CONCLUSION

This paper deals with the improvement of sensor less BLDC motor fed from CUK converter MPC control technique. The improved performances of sensor less BLDC motor with MPC control technique is verified to maintaining the DC link voltage of the converter. Converter is controlled by FLC controller. The DC link voltage, speed and torque characteristics are achieved using MPC, and FLC control methods. The performance of the proposed sensor less BLDC motor drive fed from DC source powered CUK converter is verified through MATLAB/Simulink.

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