

BLDC MOTOR DRIVE ANALYSIS ON TWO LEG INVERTER

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ABSTRACT

Earlier for variable speed application conventional motors were used, but these motors have poor characteristics. These drawbacks were overcome by brushless DC motor drive. Now days in most of the applications such as industrial, domestic, aerospace, defense, medical and traction etc, brushless DC motor (BLDCM) is popular for its high efficiency, high torque to weight ratio, small size, and high reliability, ease of control and low maintenance etc. BLDC motor is a electronic commutator driven drive i.e. it uses a three phase voltage source inverter for its operation, electronic devices means there is a problem of poor power quality, more torque ripple and speed fluctuations. This paper deals with the CUK converter two leg inverter fed BLDCM drive in closed loop operation. The proposed control strategy on CUK converter two leg inverter fed BLDCM drive with split DC source is modeled and implemented using MATLAB/Simulink. The proposed method improves the efficiency of the drive system with Power factor correction feature in wide range of the speed control, less torque ripple and smooth speed control.

1. INTRODUCTION

Technology is for human convenience and innovation of electric motors gave scope to reduce the efforts put in by human mankind in many applications especially in industries. Electric motor is an electro-mechanical device which converts electrical energy to mechanical energy. Motors can be broadly classified in to DC type and AC type of motors. DC motor exhibits fine speed characteristic which are very much a constraint in many of the applications. DC motors are simple in construction and has good torque characteristics. Commutation is done with the help of brush-commutator assembly. Brush is a static device which collects current from or in to machine via commutator. Commutator is a rotating device which transforms supplied DC to alternating type to armature. Due to the presence of commutator and brush assembly in conventional DC motors, additional losses are produced and with resulting sparks. This phenomenon affects the overall system efficiency. To improve the system efficiency and to reduce additional losses produced due to brush-commutator assembly, brushless DC motors are developed constructed

without the need of brushes and commutator for commutation [1]-[3].

Brushless DC (BLDC) motors are synchronous motors developed eliminating brush-commutator assembly. BLDC motor is constructed with armature on its stator and permanent magnets on its rotor [4]-[5]. BLDC motor does not consist of windings on both stator and rotor thus consuming less copper and less reactive power absorption as compared with induction motor which has windings on both stator and rotor. Solid state electronic switches carries electrical commutation in BLDC motor excluding the use of brush-commutator assembly as in conventional DC motors. This type of construction can improve system efficiency with increased performance. Stator windings of BLDC motor are excited with alternating three-phase currents producing rotating magnetic field. Rotating magnetic field interacts with the rotor flux and torque is exerted on rotor. BLDC motor can run at high speeds with low acoustic noise. High efficiency and reliability also makes BLDC motor a better choice for many applications [6]-[7].

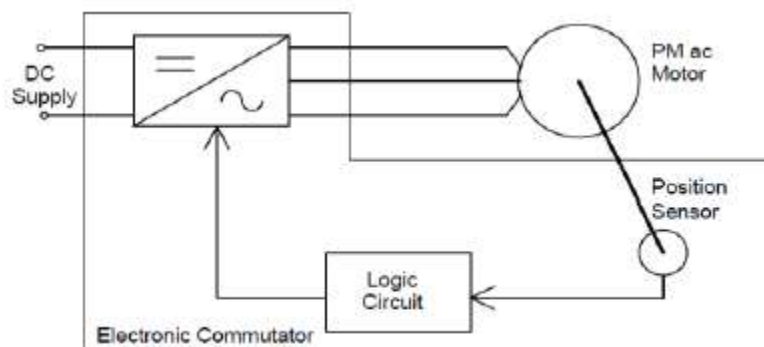


Figure 1. Typical BLDC motor

Typical BLDC motor is shown in Figure 1. BLDC motor consists of front-end converter which converts given DC supply to AC. Though name suggests it is DC motor but in operation it is a synchronous motor. After conversion of DC to AC, phase windings are excited and thus motor rotates with the principle of electro-magnetic induction.

In operation, the supplied AC will be converted to DC (since general available supply will be of AC type) and again in front end converter, DC is converted to AC when BLDC is connected to main supply system. Presence of front-end converter for BLDC motor which is typically a power electronic converter draws non-linear components of source currents and induces harmonic components in source components [8]. This phenomenon of inducing harmonics in source components and reduces the power factor of the system and reduces the system efficiency and performance. This property in BLDC insists for power factor correction.

Many control strategies were proposed and this paper presents a current controlled buck converter for power factor correction in BLDC drive system. This power factor correction control is based on current follower. Rotor speed and positions were sensed and are used for current control. Static switch in buck converter is operated from control strategy and power factor in the system was corrected. A total harmonic distortion for the system was presented for different cases. Control strategy

was tested for conditions of different DC link voltages and step-change in DC link. BLDC motor characteristics were also shown for different cases.

2. OPERATION OF CUK PFC TWO LEG INVERTER FED BLDCM DRIVE

Figure 1 shows the schematic diagram of proposed CUK PFC two inverter fed BLDCM with split DC supply for speed control as well as PFC in wide range of input AC voltage. It consist of two schemes one is Power factor correction control scheme which uses a current multiplier approach concept with a current control loop inside and second one is the speed control loop for continuous-conduction-mode operation of the converter. First reference DC link voltage is compared with the actual DC link voltage which generates the DC link voltage error signal (V_{dc_error}), which is processed through a PI controller to generate control signal (I_c). This control signal multiplied with a unit template of input ac voltage to get reference DC link current (I_{dc_ref}). This reference DC link current (I_{dc_ref}) is compared with dc link current (IDC) which is sensed after diode bridge rectifier. The resultant DC current error (IDC_err) is amplified and compared with a saw tooth carrier wave of fixed frequency (F_s) to generate the pulse width modulation (PWM) pulse for the Cuk converter. Its duty ratio (D) at a switching frequency (F_s) controls the dc link voltage at the desired value. For speed control

reference speed is compared with actual speed of the motor which gives speed error (N_{err}) which is processed through PI controller, which give reference current signal (I_{ref}), this reference current signal is multiply with hall sensor current position information, which generate the reference stator current signal (I_{a_ref}). This reference stator current signal (I_{a_ref}) processed with hysteresis controller to generate the firing pulse for voltage source inverter.

3. BLDC MOTOR WITH BUCK CONVERTER

Generally the available supply is AC and for a BLDC motor to operate needs DC. For this conversion of AC to DC, a diode bridge rectifier is used. Diode bridge rectifier converts AC to DC and the DC output is fed to buck converter. Buck converter is DC-DC converter which is typically a step-down converter. A high voltage DC is stepped down to low voltage DC using a buck converter. Obtained low voltage DC is fed to inverter which is voltage source converter through a filter and DC link from capacitor. Inverter produces three phase output and the stator windings of BLDC motor are excited. When stator windings are excited rotating magnetic field is produced and due to interaction of stator and rotor fields. Torque is exerted on rotor. The rotor position is continuously sensed by sensors and sent to electronic commutation which triggers static switches of voltage source converter (front-end converter for BLDC). Due to the presence of diode bridge rectifier for conversion of AC to D

4. POWER FACTOR CORRECTION WITH BUCK CONVERTER FOR BLDC MOTOR

For conversion of available AC supply to DC, a diode bridge rectifier is used. Presence of non-linear devices connected to the system induces harmonics in to the source components as they draw non-linear components. This injection of harmonics or presence of harmonics in source components affects the performance of the system reducing efficiency. Power factor is mainly affected due to presence of harmonics and increases the system losses. BLDC motor with power factor correction is shown in Figure 2. The rectified output from AC converting to DC is fed to buck converter where power factor correction takes place. Power factor correction is done by proper switching of static switch in buck converter. Switching signals were obtained from the control circuit output.

Speed reference is taken and is converted to voltage signal. Obtained reference voltage is compared with actual DC link voltage and error signal is sent to PI controller for error reduction obtaining current magnitude. From source voltage, information regarding sine is obtained and combined to current magnitude obtaining reference current signal. The obtained reference current signal is compared to actual current and error signal is sent to hysteresis current controller which produces gating pulses to buck converter.

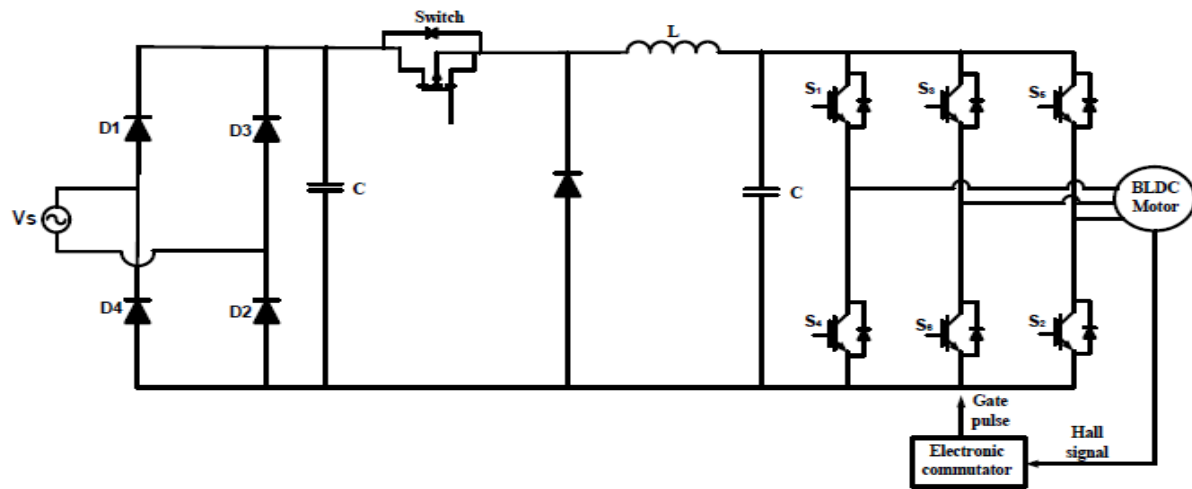


Figure 2. BLDC motor with Buck converter without control

CONCLUSION

Brush and commutator assembly in conventional DC motors gives additional losses which reduces the system efficiency with additional losses and wear and tear. Elimination of brush and commutator for electric commutation can improve system performance. Brushless DC (BLDC) motors constructed without presence of mechanical commutator and brushes can give better performance with enhanced efficiency making use of electronic commutation. Use of front-end converters for conversion of power from one form to other for operation of BLDC motor induces harmonics in to the system deteriorating power factor. Power factor correction in the system was done using a buck converter controlled with current control technique. Implication of current control strategy with buck converter for power factor correction was found suitable and was tested for different DC link voltages and also for step variation in DC link voltage. Buck converter with current control strategy was explained. Total harmonic distortion in source current was kept within normal limit and was shown. Power factor for different cases was maintained nearer to unity as no phase shift between source current and voltage was observed from shown results. Current controlled buck converter can improve

power factor of the system which is very essential in any system.

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