Speed control of motor-driven medical devices using converter-based techniques

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ABSTRACT

This paper presents the smooth speed control of a permanent magnet brushless DC motor drive (PMBLDCM) for an air conditioner. The bridgeless single ended primary inductor converter is used for proposed scheme. A bridgeless single ended primary inductor converter is basically boost converter followed by buck –boost converter. An analysis of speed control of permanent magnet brushless DC motor drive is done. The proposed scheme is used to combine the power factor correction controller and DC link voltage control in a single stage. With the implementation of proposed scheme conduction losses will be less. A single switch topology is used for the proposed speed control scheme. For the better speed control of a PMBLDC motor drive, it is essential to control a DC link voltage. The Dc link voltage is proportional to the speed of BLDC motor drive. Power factor at input side can be control with the help of proposed scheme. A power factor correction (PFC) controller is design discontinuous Current Mode (DCM). A rate limiter is used for control torque and current in PMBLDCM at DC link. With the help of proposed scheme power factor correction (PFC) controller provides better power quality at input AC mains. From the analysis of various results obtained after simulation of BL-SEPIC it is observed that speed of a permanent magnet brushless DC motor drive can be control in smooth manner with power factor correction at input side. The proposed scheme is designed and results are shown in MATLAB Simulink Environment.

Keywords: PMBLDCM, BL-sepic, PFC, DCM, power quality, VSI

INTRODUCTION

The permanent magnet brushed less DC motors is being used in low power as well as high torque applications. PMBLDCM's have features like high efficiency and wide speed range. Maintenance required for PMBLDCM's is also low as compare to other motors. Permanent magnet brushed less DC motors are more reliable as compare to other, one of them reasons are, they have better speed versus torque characteristics, high speed response and noiseless operation [1-4]. Permanent magnet DC motors are classified in different types such as, permanent magnet brushed less DC motors and permanent magnet synchronous motors (PMSM). Permanent magnet synchronous motors have sinusoidal back emf waveform and permanent magnet brush less DC motors have trapezoidal back EMF waveform. BLDC motors are electronically commuted. Brushes are not use for commutation. Due to this construction, many losses such as sparking, wear and tear of brushes, noise and electromagnetic interference can be neglected. For detection of rotor position hall sensors are being employed in brushed less DC motors. The brushed less DC motors are fed from single phase ac mains through diode bridge rectifier. Due to this, pulsed current having a peak value higher than the amplitude of fundamental input current of AC mains [5]. DC link capacitor results various power quality issues, such as poor power quality factor, increased at input side [6] due to uncontrolled charging of

DC link capacitor. A bridgeless single ended primary inductor converter (BL-SEPIC) based power factor correction (PFC) converter is implemented in this work for PMBLDCM's. The proposed scheme is more advantageous because only one controller is required for operation [6]. Speed control of PMBLDC motor has lots of advantages. PMBLDC motor can be used in home appliances as well as in industrial appliances also. Used of PMBLDC motor gives reliable results in various applications. One of the common applications are aerospace as well as automation industries also [7-8]. PMBLDC motor can also be used in air conditioner. So, due to speed control of PMBLDC motor it becomes more reliable for use. In proposed scheme bridgeless rectifier is used instead of bridge rectifier. So, conduction losses can be minimizing due to implementation this scheme. Due to use of bridgeless rectifier power quality issues like power factor, harmonic distortion as well as switching losses can be minimizing [9]. There are two modes of operation of power factor correction converter. These operational modes are current continuous mode and discontinuous current mode. In proposed scheme discontinuous current mode is implemented. So, due to implementation of discontinuous current mode, low amount of sensing is required [7].

PROPOSED MODEL OF BL-SEPIC CONVERTER

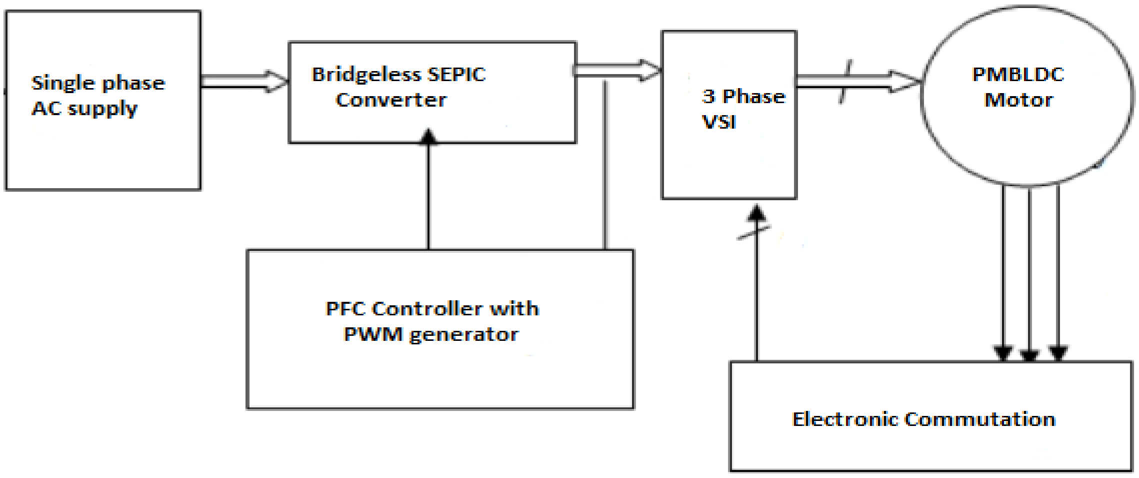

Fig.1: Block Diagram of BL-SEPIC Fed PMBLDCM.

OPERATION OF BL-SEPIC

Figure 2 shows bridgeless rectifier for operation of proposed scheme. Bridgeless rectifier is used to convert ac supply into dc output.

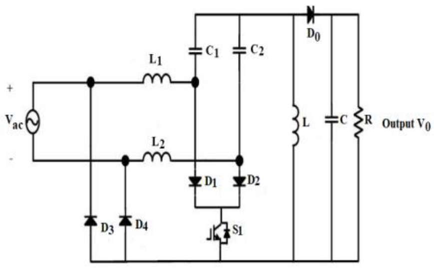

Fig.2: Bridgeless SEPIC Converter.

Bridgeless rectifier circuit is connected to SEPIC operated in two half cycle i.e. Positive half cycle and negative half cycle. Bridgeless rectifier operated at two stages ie. When switch S1 is at ON state and switch S1 is at OFF state. During positive half cycle, BL-SEPIC circuit is active through diode D4. Diode D4 is used to connect input side to output. During negative half cycle, BL-SEPIC is active through diode D3. Diode D3 is also used for connect input side to output. When switch S1 is at ON stage then that time rectifier gets operated through diode D4 and diode D3 gets reversed biased due to input voltage.

When S1 is at ON Stage
When S1 is at ON stage then that time diode D1 is at turned OFF stage. From input AC voltage side inductor gets charged then C1 also gets charged and it transfers energy into output side L. At this stage, inductor L is remaining in charging state. Output of capacitor C is load current. Figure 3 shows the operation of BL-SEPIC converter when switch S1 is at ON stage.

When S1 is at OFF Stage
When S1 is at OFF stage then that time diode D1 is also at ON stage. From input AC voltage side inductor L1 gets charged. At that time, Capacitor C1 also gets charged and due to this it provides load current. When output capacitor C gets charged then L2 is connected to the load side for providing a load current. Figure 4 shows the operation of BL-SEPIC converter when switch S1 is at OFF stage.

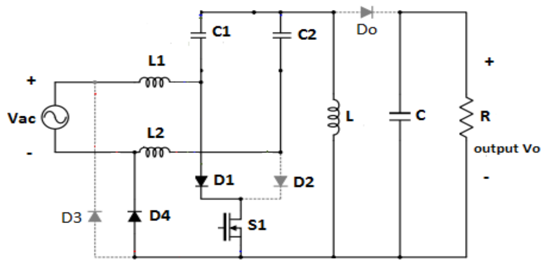

Fig.3: When Switch S1 at ON Stage.

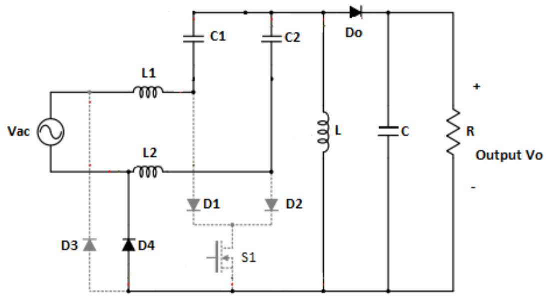

Fig.4: When Switch S1 at OFF Stage.

For the Proposed Model of BL-SEPIC
Considering,
Vs= 220 V and 600 W load.
fs = 40 KHz and Is = 4.12 A

$$Vin = \frac{2\sqrt{2}Vs}{\pi}$$

Duty ratio is given by, $D = \frac{Vin}{Vin+Vdc}$

$$Vdc = \frac{Vin}{D} - Vin \ \& \ Idc = \frac{P}{Vdc} \quad \dots (1)$$

$\Delta Vc1 = 10\% \text{ of } Vdc$

$\Delta ILo = \text{Considering } 2\% \text{ of } Is$

$$L1 = L2 = \frac{DVin}{fs * \Delta Vc1} \quad \dots (2)$$

$$C1 = C2 = C = \frac{DIdc}{fs * \Delta Vc1} \quad \dots (3)$$

$$L = \frac{(1-D)Vdc}{fs * \Delta ILo} \quad \dots (4)$$

$$Cd = \frac{DIdc}{fs * \Delta Vc1} \quad \dots (5)$$

Based on above calculations, above values are used for simulation study.

Motor Specifications
Trapezoidal motor, rated torque= 1.4 N-m, rated speed=2000 rpm, reference speed=2000 rpm, rated DC link voltage=230 V.

Reference voltage generator
The output of permanent magnet brushed less DC motor is proportional to voltage which is generated by reference voltage generator.

Rate limiter

In transient condition, voltage error at DC link is kept constant by using rate limiter. So that, it is very useful for proposed scheme to control speed of PMBLDC motor.

Electronic commutation

In most cases, brushless DC motor consists of stator windings. In a brushed less DC motors, commutation process is an important process for enabling rotor rotation. Stator windings of PMBLDCM drive gets energized to positive power for each commutation. It indicates that, current enters in the winding. Second winding as a negative. For the running purpose of motor, it is necessary to shift the position of magnetic field produced by windings. For maintaining rotor in running condition it is necessary to excite winding sequentially. This can be done with the help of electronic switches, ON and OFF sequentially. In other manner, procedure of activating current flow in six directions via suitable motor phase windings to create an output torque is known as electronic commutation.

H_a	H_b	H_c	S_{a1}	S_{a2}	S_{b1}	S_{b2}	S_{c1}	S_{c2}
0	0	0	0	0	0	0	0	0
0	0	1	0	0	0	1	1	0
0	1	0	0	1	1	0	0	0
0	1	1	0	1	0	0	1	0
1	0	0	1	0	0	0	0	1
1	0	1	1	0	0	1	0	0
1	1	0	0	0	1	0	0	1
1	1	1	0	0	0	0	0	0

PFC controller

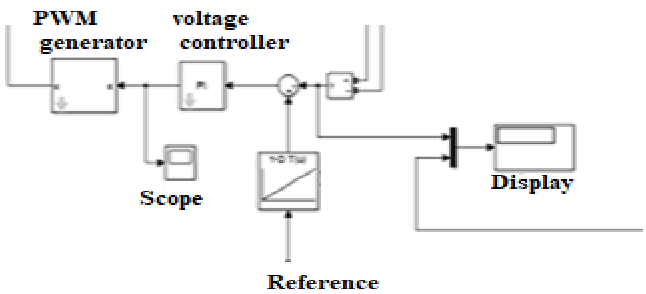

Fig.5: PFC Controller.

Voltage controller

It is a proportional integral controller. PI controller is used to provide controlled output. The value of gain is set by taking trial in MATRIX LABORATORY.

PWM generator

The output of proportional integral controller is given to a PWM generator. This PWM generator is used to produces a PWM signal of fixed frequency and varying duty ratio. boost PFC converter shown in Figure 5 and given as,

If kdcIc(k) > md(t) then S = 1

If kdcIc(k) <= md (t) then S = 0

The output of proportional integral controller is given to a PWM generator. This PWM generator is used to produces a PWM signal of fixed frequency and varying duty ratio.

SIMULATION RESULT OF BL-SEPIC CONVERTER

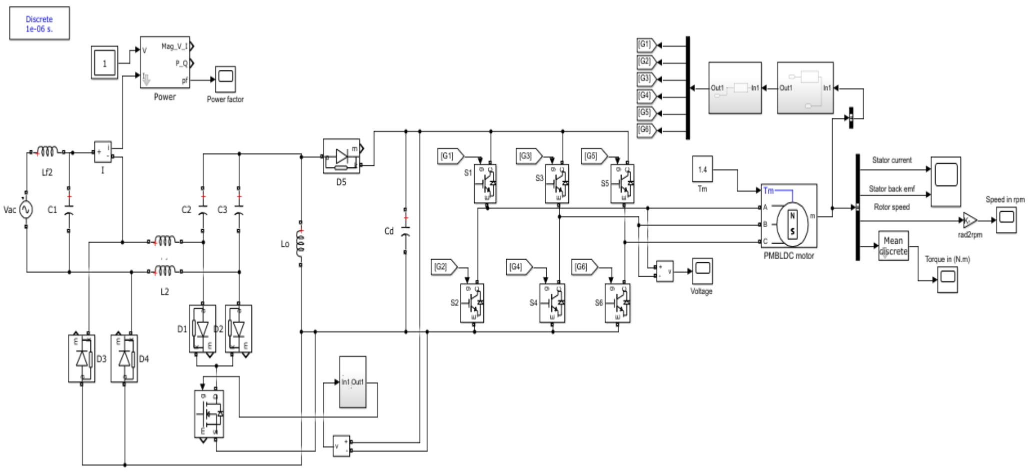

Fig.6: Simulation Diagram BL-SEPIC Converter Fed Brushless DC Motor.

Figure 6 shows MATLAB simulation diagram of bridgeless single ended primary inductor conveter.A 150V to 220V, 50HZ AC supply is fed to motor. A BL-SEPIC is used to control the speed of brushless DC motor and improve power quality at input side.

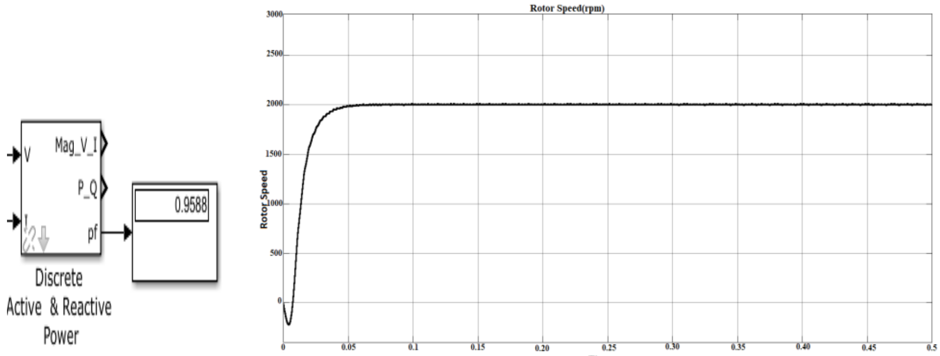

Fig.7: Power Factor of BL-SEPIC fed PMBLDCM and Rotor speed of BL-SEPIC fed PMBLDCM.

Table 1: Speed and Power Factor at Different Value of Applied Voltage for SEPIC and BL-SEPIC fed PMBLDCM at Constant Load.

Applied voltage (V) at 50 Hz	Power Factor	Power Factor	Speed (RPM)	Speed (RPM)
	SEPIC fed PMBLDCM	BL-SEPIC fed PMBLDCM	SEPIC fed PMBLDCM	BL-SEPIC fed PMDLDCM
150 V	0.824	0.95	2000	2000
170 V	0.849	0.95	2000	2000
190 V	0.827	0.94	2000	2000
220 V	0.829	0.94	2000	2000

CONCLUSION

A PFC BL-SEPIC converter fed permanent magnet brushed less DC motor drive is simulated in MATLAB/Simulink environment and implemented. Power factor correction converter is operated in discontinuous current mode. The conduction losses also be reduced due to proposed scheme of BL-SEPIC. The speed control of PMBLDCM can be achieved smoothly with the help BL-SEPIC Speed control of PMBLDCM drive can be achieved with help of proposed schemes. For speed control operation reference speed is used. A BL-SEPIC converter ensured near unity power factor at input ac mains. However, considering overall performance of converter, BL-SEPIC fed PMBLDCM is more reliable.

FUTURE SCOPE

In this technology the controlling of BLDC Motor can be done in simplified manner so that, in future there will be a successive scope for controlling the proposed Motor. Also the Motor of low rated rpm as well large rpm Motor can control. So that in future, implement this technique on the large rpm Motor in various applications. This technology is more advantages because of wide range of speed controller, hence useful for various low power applications. Demand of automation industries are increased, so to fulfill the requirements of automation industries proposed schemes are very useful. In automation industries, requirement of adjustable speed is more hence proposed schemes are very useful.

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