



A Novel PFC Zeta Converter for Speed Control of PMBLDC Motor

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ABSTRACT: A novel PFC (Power factor Correction) converter using ZETA DC–DC converter feeding a BLDC (Brush Less DC) motor drive is proposed. A single phase supply followed by an uncontrolled bridge rectifier and a Zeta DC-DC converter is used to control the voltage of a DC link capacitor which is lying between the Zeta converter and a VSI (Voltage Source Inverter). Voltage of a DC link capacitor of Zeta converter is controlled to achieve the speed control of BLDC motor. The proposed PMBLDCM drive is designed and its performance is evaluated in Matlab–Simulink environment and the hardware is implemented on PCB.

KEYWORDS: Power factor correction (PFC), Permanent magnet (PM) brushless dc motor (PMBLDCM), Zeta converter, voltage source inverter (VSI).

I. INTRODUCTION

International concern of power quality problems and pollution has prompted the use of power factor correction converters with permanent magnet brushless DC motors for numerous low power applications. Since, the Brushless DC motor is the ideal choice for the applications that require high reliability, high efficiency and low maintenance [5]. Since it does not have any brushes to wear out and replace, generally speaking, BLDC motor is considered to be a high performance motor that is capable of providing large amounts of torque and speed performance curve characteristics. These PMBLDCMs are fed from single phase AC mains through diode bridge rectifier (DBR) followed by a DC capacitor. However this will result in pulsed AC current which will affect the power factor results in power quality disturbances (PQ). This is due to uncontrolled charging of the DC capacitor leading to peak value higher than the amplitude of the fundamental input current at AC mains. In order to drive the PMBLDC motor with power quality improvement it needs PFC converter topology among various available topologies [1].

The basic DC-DC converter topologies [1] using Buck – converter, Boost converter and Buck – Boost converter have their intrinsic limitations when used for active power factor correction along with voltage regulation purpose. Among the new classes of DC-DC converters CUK, SEPIC and Zeta, in the proposed model a Zeta converter is used for active PFC and voltage regulation having advantages of being naturally isolated structure, can operate as both step up and step down voltage converter and having only one stage processing for both voltage regulation and PFC[4].

A Zeta converter is a fourth order non linear system performs a non-inverting buck-boost function. But in application which implies high power, the operation of a converter in discontinuous mode is not attractive because it results in high rms values of the current causing high levels of stress in the semiconductors[2]-[3]. In this paper, an active power factor correction PFC is performed by using a Zeta converter operating in continuous conduction mode (CCM), where the inductor current must follow a sinusoidal voltage waveform. This method provides nearly unity power factor with low THD. The proposed model improves the power factor and wide range of speed control of PMBLDC motor.

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II. PROPOSED SPEED CONTROL SCHEME OF PMBLDC MOTOR DRIVE

Fig1 shows the proposed speed control scheme which is based on the control of the dc link voltage reference as an equivalent to the reference speed. However, the rotor position signals acquired by Hall-effect sensors are used by an electronic commutator to generate switching sequence for the VSI feeding the PMBLDC motor.

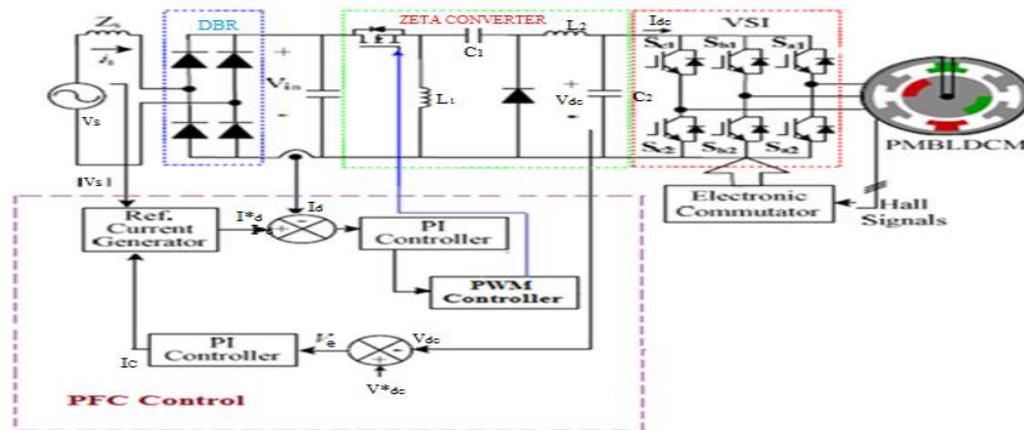


Fig – 1: Proposed PFC ZETA converter-fed VSI-based PMBLDCM.

The ZETA dc–dc converter controls the dc link voltage using capacitive energy transfer which results in non-pulsating input and output currents. The PFC control scheme uses a current multiplier approach with a current control loop inside the speed control loop for continuous-conduction-mode operation of the converter. The control loop begins with the processing of voltage error (V_e), obtained after the comparison of sensed dc link voltage (V_{dc}) and a voltage (V_{dc}^*) equivalent to the reference speed, through a proportional–integral (PI) controller to give the modulating control signal (I_c). This signal (I_c) is multiplied with a unit template of input ac voltage to get the reference dc current (I_d^*) and compared with the dc current (I_d) sensed after the DBR. The resultant current error (I_e) 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 ZETA converter. Its duty ratio (D) at a switching frequency (f_s) controls the dc link voltage at the desired value.

III. DESIGN OF PFC CONVERTER BASED PMBLDCM DRIVE PROPOSED

The proposed PFC ZETA converter is designed for a PMBLDC motor drive with main considerations on the speed control of the motor and PQ improvement at ac mains. The dc link voltage of the PFC converter is given as

$$V_{dc} = V_{in} * D / (1 - D)$$

Where, V_{in} is the average output voltage of the DBR for a given ac input voltage (V_s) related as

$$V_{in} = 2 \sqrt{2} V_s / \pi$$

The ZETA converter uses a boost inductor (L_1) and a capacitor (C_1) for energy transfer. Their values are given as

$$L_1 = D * V_{in} / \{f_s (\Delta I_{L1})\}$$

$$C_1 = D * I_{dc} / \{f_s \Delta V_{C1}\}$$

Where ΔI_{L1} is a specified inductor current ripple, ΔV_{C1} is a specified voltage ripple in the intermediate capacitor (C_1), and I_{dc} is the current drawn by the PMBLDCM from the dc link.

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A ripple filter is designed for ripple-free voltage at the dc link of the ZETA converter. The inductance (L_2) of the ripple filter restricts the inductor peak-to-peak ripple current (ΔI_{L2}) within a specified value for the given switching frequency (f_s), whereas the capacitance (C_2) is calculated for the allowed ripple in the dc link voltage (ΔV_{C2}). The values of the ripple filter inductor and capacitor are given as

$$L_2 = (1 - D) V_{dc} / \{f_s(\Delta I_{L2})\}$$

$$C_2 = I_{dc} / (2\omega\Delta V_{C2})$$

The PFC converter is designed for a base DC link voltage of $V_{dc}=298V$ at $V_s=220V$ for $f_s=40kHz$, $I_s=4.12A$, specified input inductor current ripple $\Delta I_{L1}=0.82A$ (20% of I_{dc} , & $I_{dc}=3.5A$), peak to peak filter inductor ripple current $\Delta I_{L2}=0.35A$ (10% of I_{dc}), ripple in the DC link voltage $\Delta V_{C2}=5.96V$ (2% of V_{dc}), voltage ripple in the intermediate capacitor $\Delta V_{C1}=4.4V$ (2% of V_s). The design values are obtained as $L_1=3.6$ mH, $C_1=239nF$, $L_2=0.85$ mH, $C_2=935\mu F$.

IV. PERFORMANCE OF PROPOSED PFC DRIVE AND SIMULATION RESULTS

The performance of the Open loop Zeta converter without PFC control, driving PMSBLDC motor is simulated using Matlab-Simulink.

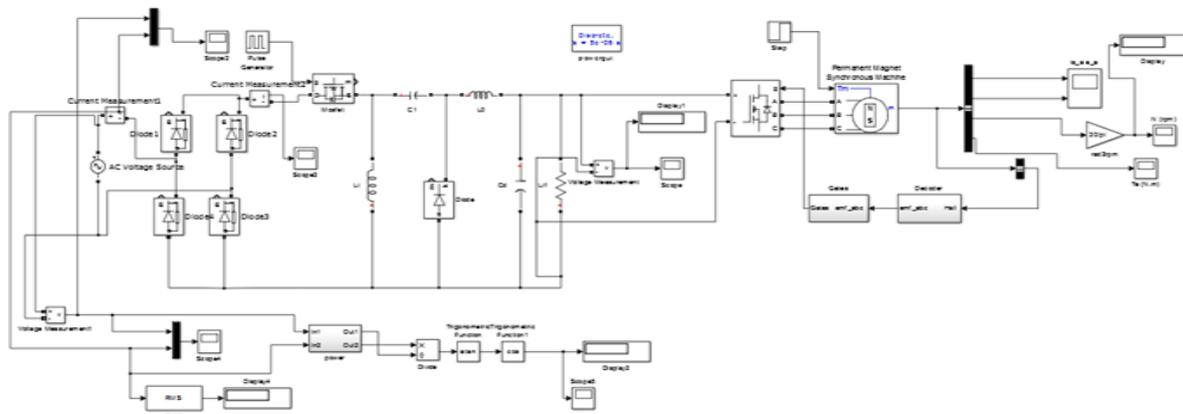


Fig- 2: open loop simulink model of proposed circuit without PFC

At AC mains voltage of 220V, 50Hz supply, the zeta converter gives the output dc link voltage of 298V, Speed 2900 rpm and power factor is 0.8978 with a duty cycle of 0.6. The output voltage, speed and power factor waveform is shown in fig.3 respectively.

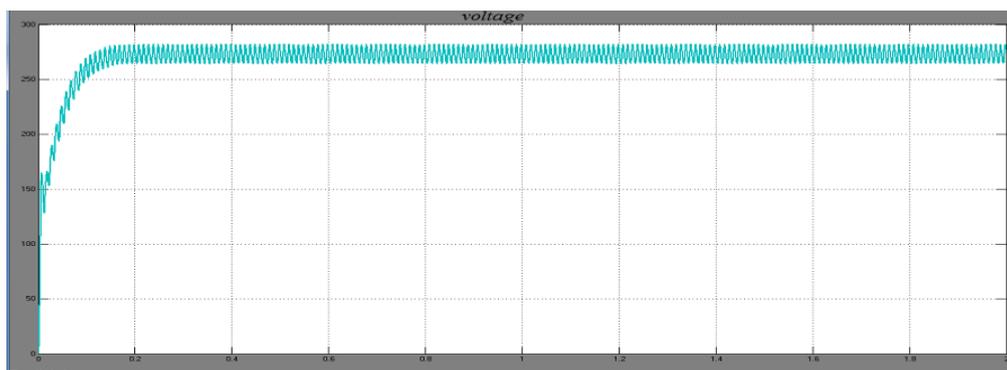


Fig.3: (a) output voltage of zeta converter

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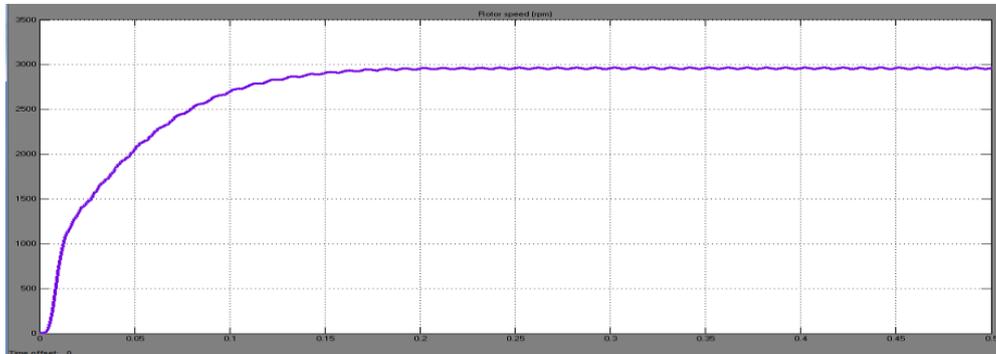


Fig.3: (b) Speed of PMBLDC Motor

Fig.3 (b) shows the speed curve of PMBLDC Motor for a dc link voltage of 298v at 60% duty cycle as 2900rpm.

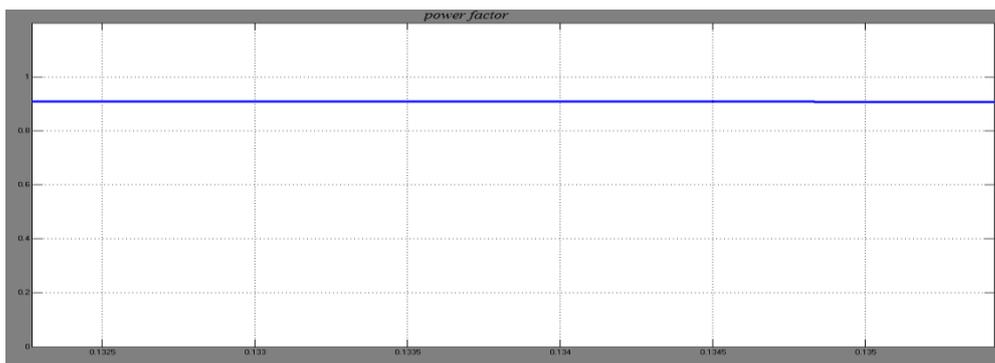


Fig.3 (c) power factor waveform

Therefore in open loop PFC Zeta converter for PMBLDC drive, from the above fig.3(c), it is clear that PF is very low (0.8878). As we know this will reduce the power quality of the system. Therefore for the power quality improvement PFC control block is added in the feedback loop to obtain optimum performance of the PMBLDC motor with PFC Zeta converter.

The Proposed PMBLDC drive with the combination of PFC converter is simulated in MATLAB-Simulink is shown in fig.4

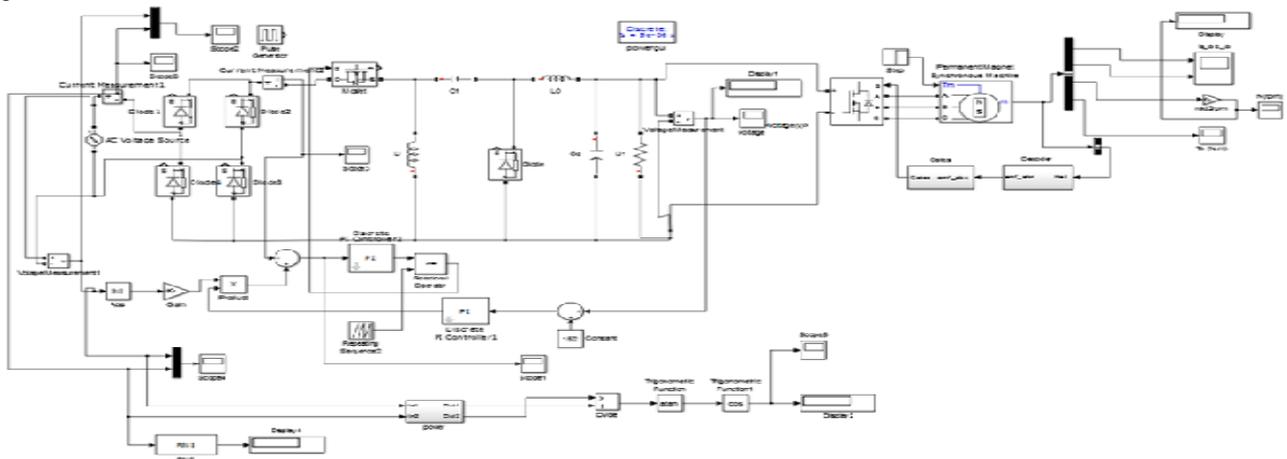


Fig- 4: closed loop simulink model of proposed circuit with PFC

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In closed loop PFC zeta converter for PMBLDC motor, the input AC voltage is set at 220V, 50Hz and the power factor is improved to 0.9995 and the output voltage is maintained at 298V by controlling duty cycle of MOSFET switch of zeta converter by PWM controller and PI controller as 0.6. The speed of PMBLDC motor is 2900rpm at 298V which is shown in fig.5 (a).

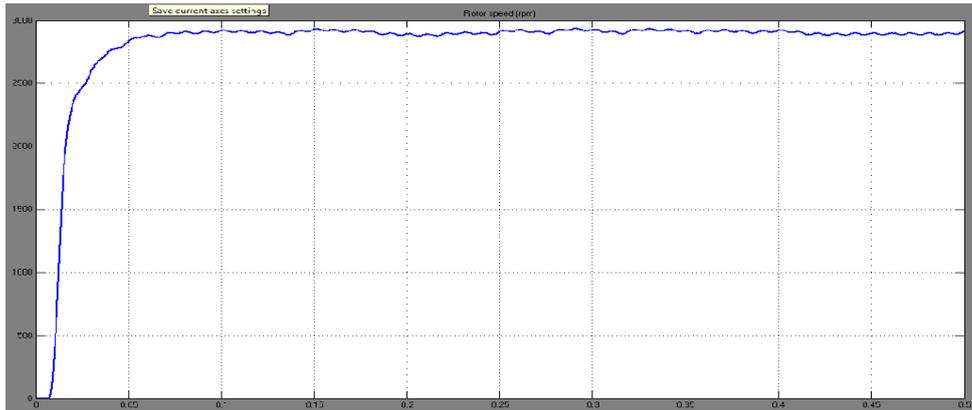


Fig5 :(a)Speed of PMBLDC Motor

It is clearly shown in the fig.5 (b) that the input current power factor is 0.9995. Hence the power quality and performance of the PMBLDC motor drive is improved.

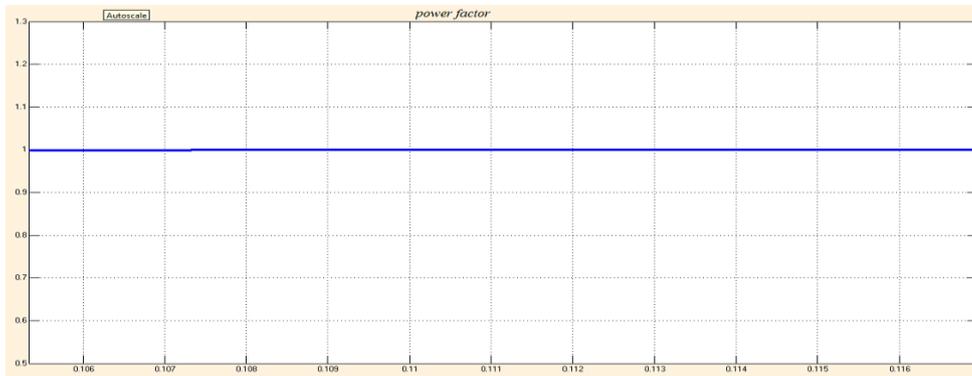


Fig.5: (b) power factor waveforms

Therefore by adjusting the reference speed equivalent to DC link voltage wide range of speed control can be obtained which is shown in the Table I.

Table I: Performance of The Proposed PMBLDC Motor Drive under Speed Control at 220V input Ac Voltage

DC link voltage (V_{dc})	Speed (rpm)	Power factor (PF)
152	1300	0.8823
180	1610	0.9306
205	1890	0.9619
230	2170	0.9837
285	2790	0.9896
300	2910	0.9995

The above table shows the performance of the proposed model for the various dc link voltage and its clear that as the dc link voltage increases the speed of the motor increases along with the increase in power factor from 0.8823 to 0.9995.hence power factor is improved in closed loop drive compared to open loop drive.

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V. HARDWARE

The hardware circuit of the PFC zeta converter driving the PMBLDC motor drive is shown in fig.6. In Hardware fabrication input 230 V AC has been stepped down to 24V and the 24V dc is fed to Zeta converter and drives the PMBLDC motor drive. The rating of the PMBLDC motor drive which is connected to the zeta converter is 1.7 watts, 24V and 3000 rpm motor. The output dc link voltage has been controlled from 3V to 24V and correspondingly speed has been changed. The PF remains nearby unity and the power quality of the proposed PFC drive is improved.

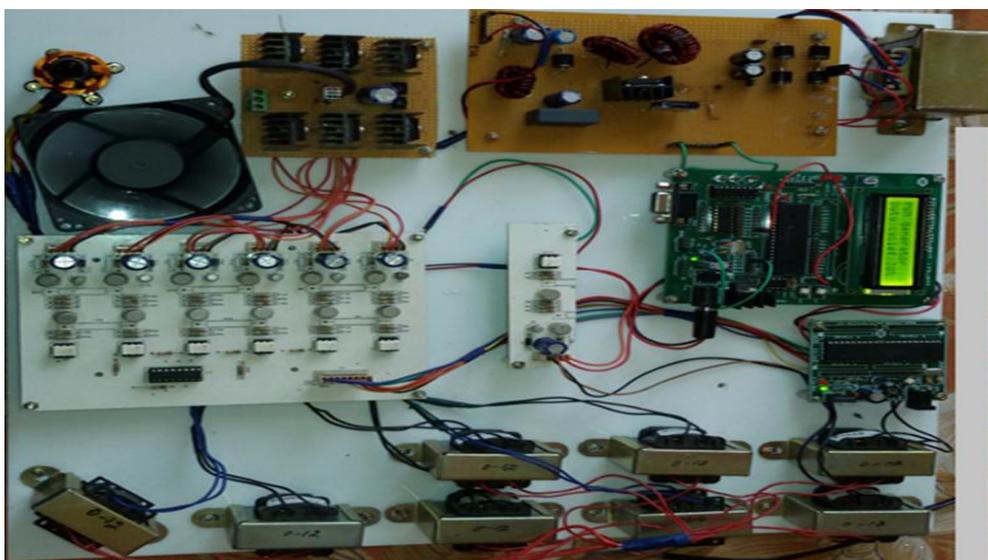


FIG. 6: hardware implementation

Table.2: Performance of Drive

PERFORMANCE OF DRIVE UNDER SPEED CONTROL AT 12V INPUT AC VOLTAGE		
DC link voltage (Vdc)	Speed (rpm)	Power factor (PF)
3.6	150	0.672
9.4	942	0.698
15.8	1530	0.847
17.9	1616	0.887
20.5	1710	0.918
21.8	1752	0.956

From the above table it is clear that as the dc link voltage increases speed of the PMBLDC Motor increases along with increase in power factor at Ac mains. Hence the power factor is improved from 0.672 to 0.956.



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VI. CONCLUSION AND FUTURE WORK

A new speed control strategy is employed for PMBLDC motor drive using PFC zeta converter. The speed of PMBLDCM has been found proportional to the DC link voltage, so by varying the dc link voltage different speed can be achieved hence a smooth speed control is obtained. On comparing converter with PFC & without PFC it can be seen that the closed loop PFC Zeta converter has ensured nearly unity PF in wide range of the speed. Hence the proposed model will provide improved power quality at the AC mains for wide range of speed. The closed loop hardware model of the project can be developed as a future work.

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BIOGRAPHY

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