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Zeta Converter Fed BLDC Motor Drive for Enhancement of Power Quality

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Abstract - *This paper presents a brushless dc (BLDC) motor drive with power factor correction (PFC) and improvement of power quality for low-power applications. Speed of the BLDC motor is controlled by adjusting the DC link voltage of the VSI. This facilitates the operation of VSI at fundamental frequency switching by using the electronic commutation of the BLDC motor which offers reduced switching losses. A Power Factor Correction buck–boost converter i.e, zeta converter is designed to operate in discontinuous current mode (DICM) to provide an inherent PFC at ac mains. The performance of the proposed drive is evaluated over a wide range of speed control and varying supply voltages with improved power quality at ac mains. The proposed strategies have been verified with the help of MATLAB/SIMULINK.*

Keywords: **BLDC motor, Zeta Converter, Power Factor Correction, Speed Control, Power Quality.**

1. INTRODUCTION

There are many techniques to improve the power quality in BLDC Motor and power factor correction at AC mains. The previous system are SEPIC (single ended primary inductance converter) and Buck-Boost converter are used separately for improving the power quality of the BLDC Motor and power factor correction. In this system, zeta converter controls the two parameters using the single converter. The BLDC Motor is most suitable for low power applications and we can also achieve the speed control of the BLDC Motor. There are no sensors are used to control the speed.

Zeta converter uses single switch and it provides overload and short circuit protections. Using a single switch in the converter, decreases the complexity of the converter operation. The zeta converter belongs to fourth order converters that can step up or step down the input voltage when the zeta converter is supplied by AC source that is act as a resistive load, so it is called as resistance emulators.

Selection of BLDC Motor over the Brushed DC Motor and induction motors

- Higher efficiency and reliability
- Less noise
- Better speed-torque characteristics and wide speed range
- Works better for low power applications
- No brush friction and EMI problem

The main aim of this paper is to improve the power quality and power factor at the AC mains and using the DC link voltage, the control of the BLDC Motor must be achieved.

2. ZETA CONVERTER

The Zeta converter has the capability of getting low or high voltage of output referred to the input value. This converter offers high efficiency compared to the SEPIC Converter and synchronous rectification can be easily implemented in this converter.

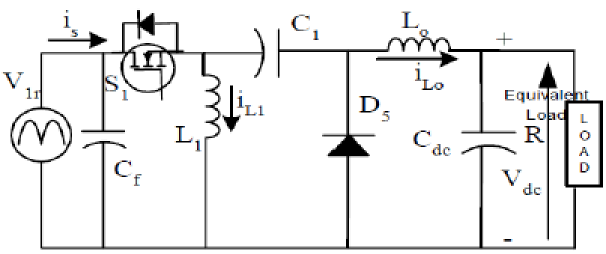

Fig -1: Circuit diagram of Zeta Converter.

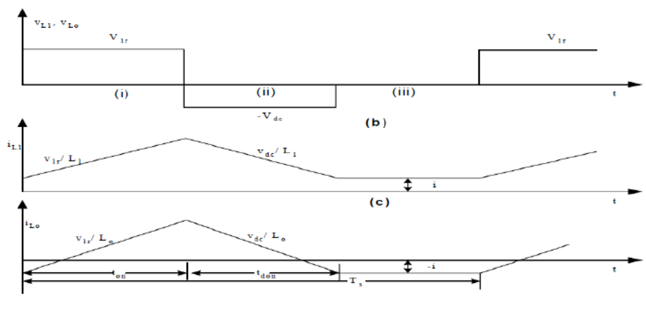

Fig -2: Waveform of Zeta Converter.

This converter operates in three modes and are as follows

Mode 1 : The switch 'S' is turned ON. The source energy is transferred to the inductor L_1 and output inductor L_0 through capacitor C_1 in turn the i_{L0}, i_{L1} are increases linearly. During this mode the output voltage is in DC value.

Mode 2 : The switch 'S' is turned OFF. The diode D starts conducting in this mode. The energy stored in the inductor L_1 and L_0 starts to supply to the output or load, meanwhile the capacitor C_{dc} maintains the voltage across the load.

Mode 3 : This is freewheeling mode until the start of new cycle, in this mode neither switch 'S' nor diode 'D' conducts. The voltage across L_1 and L_0 are zero but their currents are constant until the new switching cycle begins.

3. DESIGN OF ZETA CONVERTER

The design of zeta converter for improving the power quality at AC mains and controlling the BLDC Motor. The design equations are as follows

The output DC voltage of zeta converter is given by

$$v_d = \left(\frac{n_2}{n_1}\right) v_i \left(\frac{D}{1-D}\right) = 130\text{v}$$

where, v_i = input voltage

$$v_i = \frac{2\sqrt{2}}{\pi} v_s$$

D = duty ratio

$\frac{n_2}{n_1}$ = turns ratio of HFT

The critical value of magnetizing inductor is

$$L_m = \frac{v_d^2}{P_i} \frac{1-D}{2Df_s\left(\frac{n_2}{n_1}\right)^2} = 250\ \mu\text{H}$$

f_s = switching frequency

The output inductor is

$$L_o = \frac{v_{dc}(1-D)}{f_s K I_o} = 4.2\ \text{mH}$$

K = percentage ripple of the output current inductor i.e, 40% of inductor current

$$C_1 = \frac{v_{dc} D}{\eta\left(\sqrt{2}v_s + v_{dc}\right) f_s} \frac{P_i}{v_{dc}^2} = 0.44\ \mu\text{F}$$

η = allowable ripple voltage across C_1

and finally, $C_d = \frac{P}{v_{dc}} \frac{1}{2\omega(\eta v_{dc})} = 2200\ \mu\text{F}$

4. BLOCK DIAGRAM DISCRIPTION

A single phase AC supply is converted to DC by using the double bridge rectifier and then passed through the filter to remove the spikes in the supply for smooth DC voltage. The Zeta converter is designed to operate in dis-continuous mode (DCM) for power factor correction purpose. The filter is used to remove the spikes but it injects the harmonics into the supply and lowers the power factor at AC mains.

The reference voltage is generated based on the reference speed obtained from the BLDC Motor. The output voltage of the zeta converter is compared with the reference voltage obtained through the BLDC Motor and we obtain an error voltage. The error voltage is processed through the controller. Based on the error voltage, the pulses are generated using the PWM generator. The pulses are used to control the ON/OFF period of the switch. This makes converter conduct in discontinuous mode of operation.

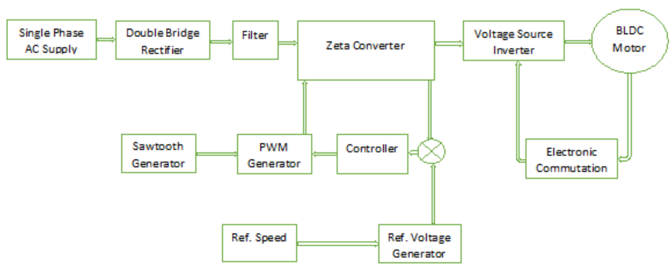

Fig -3: Power Factor Correction based BLDC Motor with Zeta Converter

5. SIMULATION RESULTS AND DISCUSSION

The below figure shows the power factor correction using zeta converter. The proposed working model has been verified by simulation technique.

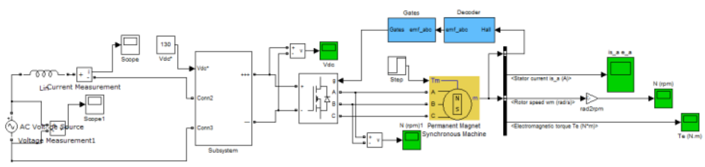

Fig -4: Power quality with Zeta converter.

The below figure shows the power quality without using the Zeta converter and clearly indicating that power quality was not improved and lower in value.

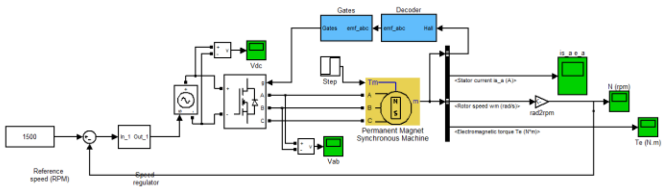

Fig -5: Power quality without Zeta converter.

5.1 Specifications of BLDC Motor

Table -1: Shows the specifications of the BLDC Motor drive.

Number of Poles	4
Rated DC Voltage	130 v
Rated Speed	1500 rpm
Rated Power	188.49 w
Voltage Constant	87.96 w
Torque Constant	0.84 Nm/A
Stator Resistance Per Phase	0.7
Rated Torque	1.4 Nm

5.2 Performance of BLDC Motor for speed control and respective power factor

Table -2: Speed range of BLDC Motor and respective power factor at AC mains.

Speed (rpm)	DC link voltage (V)	Power Factor
1350	130	0.986
1270	100	0.971

5.3 Stator Current

The below figure shows the stator current waveform when the BLDC Motor is fed by VSI with Zeta converter.

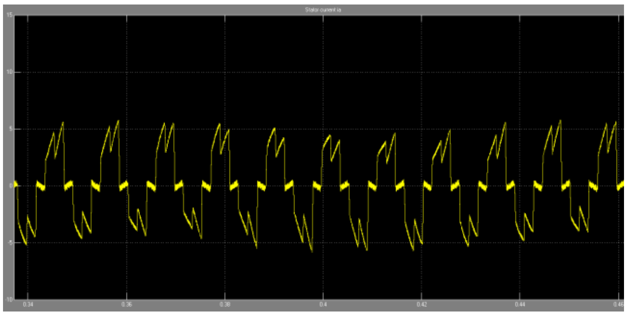

Fig -6: Stator current waveform using Zeta converter.

The below figure shows the stator current waveform when the BLDC Motor is fed by VSI without zeta converter.

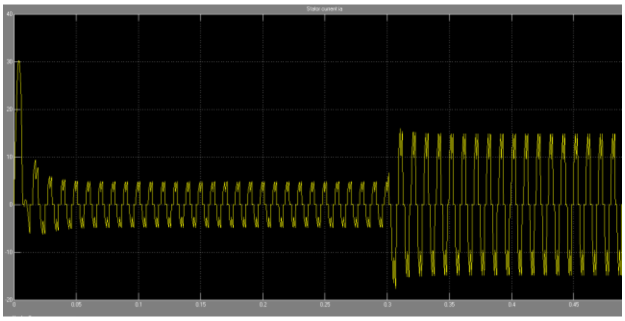

Fig -7: Stator Current waveform without Zeta converter.

5.4 Speed

The below figure shows the speed of the BLDC Motor when it is fed by VSI with zeta converter and it is indicating 1350 rpm

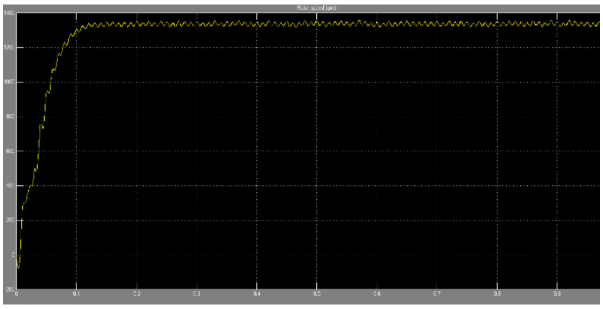

Fig -8: Speed with Zeta Converter.

The below figure shows the speed of the BLDC Motor when it is fed by VSI without zeta converter.

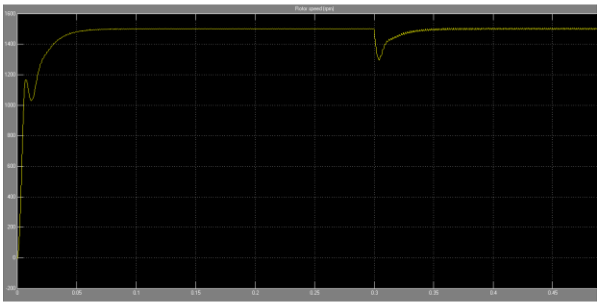

Fig -9: Speed without Zeta converter.

5.5 Torque

The below figure shows the electromagnet Torque of the BLDC Motor with zeta converter.

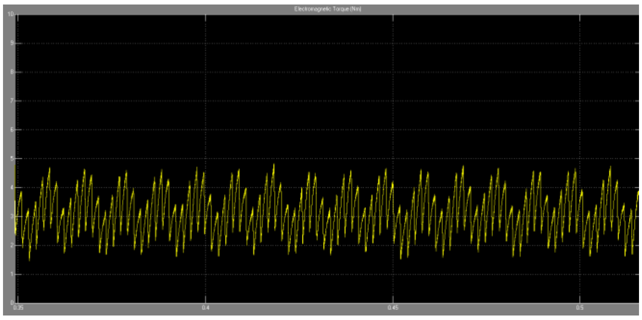

Fig -10: Electromagnet Torque with Zeta Converter.

The below figure shows the electromagnetic torque of the BLDC motor without zeta converter in the system.

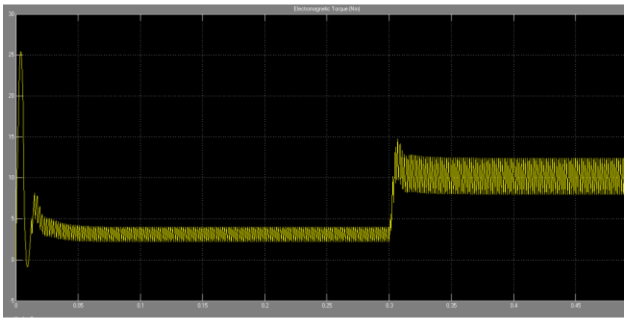

Fig -11: Electromagnetic Torque without Zeta converter.

6. CONCLUSIONS

The power quality improvement using the Zeta Converter has been proposed for low power applications. A variable DC voltage of VSI feeding BLDC Motor has been used for variable speed operation. The Zeta Converter has operated in dis continuous mode. The VSI has operated in low frequency, thus reduces the switching losses. The performance of the BLDC Motor for variable speed are satisfactory. The comparison of power quality with and without Zeta Converter has been shown. The obtained results are improved by using the Zeta Converter i.e, speed control of BLDC Motor and power quality at AC mains. The proposed strategies have been verified with the help of MATLAB/SIMULINK.

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