



PFC AND SPEED CONTROL OF BLDC MOTOR USING ZETA CONVERTER

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ABSTRACT— A Power Factor Correction (PFC) and sensorless speed control of BLDC (Brushless DC) motor using zeta converter is presented. Zeta converter is a fourth-order DC-DC converter made up of two inductors and two capacitors and capable of operating in either step-up or step-down mode. The PFC is achieved by zeta converter. Sensorless speed control of BLDC motor is achieved and the cost and wiring of sensors are reduced. A MATLAB/ Simulink environment is used to simulate the developed model to achieve a wide range of speed control with high PF (Power Factor) and improved PQ (Power Quality) at the supply.

Keywords— PFC, BLDC motor, zeta converter, sensorless speed control.

1, INTRODUCTION

International concern of power quality (PQ) problems has prompted the use of power factor correction converters with a brushless DC motors (BLDCM) for numerous low power applications. Since, the BLDCMs are employed in low power applications due to features of high efficiency and wide speed range [3]. These BLDCMs are fed from a single-phase AC supply through a diode bridge rectifier (DBR) followed by a DC capacitor. However, this practice results in a pulsed current from AC mains having various power quality (PQ) disturbances such as poor power factor (PF), increased total harmonic distortion (THD) and high crest factor (CF) of current. This is due to uncontrolled charging of the DC capacitor leading to a peak value higher than the amplitude of the fundamental input current at AC mains. Therefore, the use of a suitable power factor correction (PFC) converter topology amongst various available topologies is an essential requirement for a BLDCM drive.

A PFC converter has two categories. One is two-stage approach and the other is single-stage approach [20]. In two-stage approach, an active power factor correction stage is adopted as the front-end to force the line current tracking the line voltage. A DC/DC output stage provides the isolation and the tightly regulated output voltage to meet the load requirement. However, this approach suffers from some



drawbacks in low-power cost-effective applications because it requires additional components and complicates PFC control circuit. Thus it has high cost and large size.

A low cost alternative solution to this problem is to integrate the active PFC stage with the high quality output DC/DC stage into one stage. It is the single-stage PFC approach and in this approach, the PFC switch and its controller are saved while the converter still have fair input current and isolated high quality output[20]. Hence single stage zeta converter is proposed in this paper. The operation of a zeta converter is in discontinuous inductor current mode and hence voltage follower approach is used. In this approach the average input current follows the input voltage “naturally” The voltage follower does not need a specific controller. Because no multiplier is used and there is no problem using this type of control when the line frequency is higher than the usual value.

2, SENSORLESS SPEED CONTROL OF BLDC MOTOR

Brushless dc (BLDC) motor drives are penetrating the market of home appliances, and automotive applications in recent years because of their high efficiency, silent operation, compact form, reliability, and low maintenance. Traditionally, BLDC motors are commutated in six-step pattern with commutation controlled by position sensors. To reduce cost and complexity of the drive system, sensorless drive is preferred. The existing sensorless control scheme with the conventional back EMF sensing based on motor neutral voltage for BLDC has certain drawbacks, which limit its applications. In this paper, a novel back EMF sensing scheme, direct back EMF detection, for sensorless BLDC drive is presented. For this scheme, the motor neutral voltage is not needed to measure the back EMFs. The true back EMF of the floating motor winding can be detected during off time of PWM because the terminal voltage of the motor is directly proportional to the phase back EMF during this interval. Also, the back EMF voltage is referenced to ground without any common mode noise. Therefore, this back EMF sensing method is immune to switching noise and common mode voltage. As a result, there are no attenuation and filtering necessary for the back EMFs sensing.

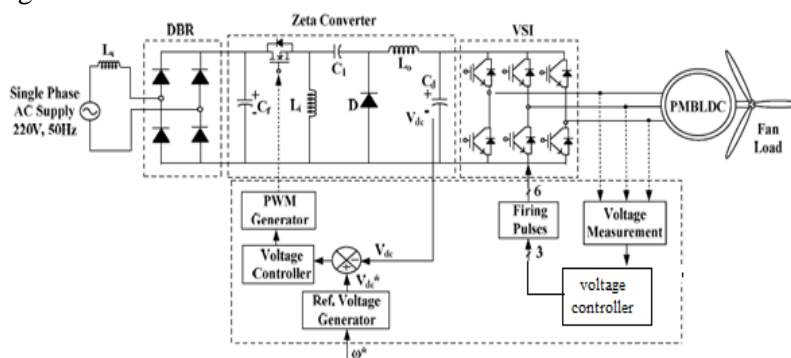


Figure.1 PFC zeta converter fed sensorless BLDC motor

3, FUNCTIONING OF THE SYSTEM

BLDC motor used in applications such as computer hard drives, small cooling fans in electronic equipments is analyzed. AC-DC conversion takes place in these drive units with a diode bridge rectifier



and a large value capacitive filter is used to reduce DC voltage ripples, which produces an increased THD of input AC mains current and excessive peak input currents leading to poor power factor. For power factor correction of the input AC mains, the buck, boost, buck-boost, Cuk and Sepic topologies are used as power factor preregulators (PFPs) [2]. Although the buck converter is self protected from overload, its devices are subjected to high rms current stress, whereas boost converters operate only in step up voltage applications. The Cuk and Sepic converters work in buck-boost mode and have inherent power factor correction. The Zeta converters operate on the principle of a buck-boost converter and have inherent power factor correction capability. It is also known as an inverse SEPIC converter. This buck-boost type converter utilizes two approaches for their control, the multiplier approach and voltage follower approach. Due to inherent advantages of the voltage follower approach[1], such as elimination of input current and voltage sensors, a simple control scheme, with only one control loop, is used for the control of AC-DC Zeta converter. The Zeta converter topology in discontinuous conduction mode (DCM) of current is employed to feed the BLDC motor. The complete scheme is shown in Fig.1.

4, MODELLING OF THE SYSTEM

The PFC DC-DC Zeta converter feeding the BLDC motor is modeled and simulated. The control scheme of the improved power quality zeta converter is shown in Fig.1. The complete model of the drive is described in the following sections.

4.1 Reference Voltage Generator:

The reference voltage generator is required to produce an equivalent voltage corresponding to the particular reference speed of the BLDC motor. The speed of BLDC motor is proportional to the DC link voltage of the VSI. The reference voltage generator produces a voltage by multiplying the speed with a constant value known as the voltage constant (K_b) of the BLDC motor.

4.2 Controller Circuit:

The controller circuit used is Proportional Integral controller. This PI controller is used to minimize the error signal and also produce a controlled output to the PWM generator to trigger the switch of zeta converter. An error voltage and the actual voltage fed from DC link capacitor is given to a PI (Proportional Integral) speed controller which generates a controlled output corresponding to the error signal.

4.3 PWM Generator:

The output of the PI controller is given to the PWM generator which produces a PWM signal of fixed frequency and varying duty ratio. A saw tooth waveform is compared with the output of PI controller.

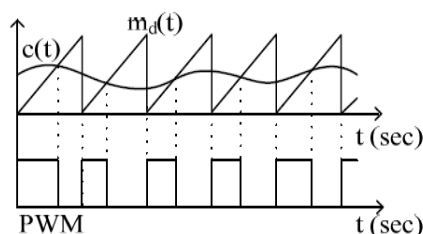


Figure.2 output of PWM signal by comparing the saw tooth signal and controlled output

4.4 BLDC motor:

The dynamic modeling of the BLDC motor is given by,

$$V_{an} = R_a i_a + P \lambda_a + e_{an} \quad (3)$$

$$V_{bn} = R_b i_b + P \lambda_b + e_{bn} \quad (4)$$

$$V_{cn} = R_c i_c + P \lambda_c + e_{cn} \quad (5)$$

The flux linkages are given as,

$$\lambda_a = L_s i_a - M(i_b + i_c) \quad (6)$$

$$\lambda_b = L_s i_b - M(i_a + i_c) \quad (7)$$

$$\lambda_c = L_s i_c - M(i_a + i_b) \quad (8)$$

where p represents the differential operator, V_{an} , V_{bn} and V_{cn} are the per phase voltages, R_a , R_b and R_c are resistances per phase, i_a , i_b and i_c are currents, e_{an} , e_{bn} and e_{cn} represents back emf and λ_a , λ_b , λ_c represents flux linkages. L_s is the self inductance per phase M is the mutual inductance of the windings.

For star connected three phase windings of the stator,

$$i_a + i_b + i_c = 0 \quad (9)$$

The flux linkages can be expressed as,

$$\lambda_x = (L_s + M) \cdot i_x \quad (10)$$

Where x denotes a, b or c (i.e. phase terminals).

4.5 Voltage source inverter:

The function of an inverter is to change a DC input voltage to a symmetrical AC output voltage of desired magnitude and frequency. The output voltage could be fixed or variable at a fixed or variable frequency. A variable output voltage can be obtained by varying the input DC voltage and maintaining the gain of the inverter constant.

5, SIMULATION MODELS AND RESULTS



The PFC and speed control of BLDC motor is simulated in MATLAB/Simulink .For various speed controls the power factor of the system is determined. The performance of PFC by varying the DC link voltage is determined and the speed control is achieved. This result is shown in table I.

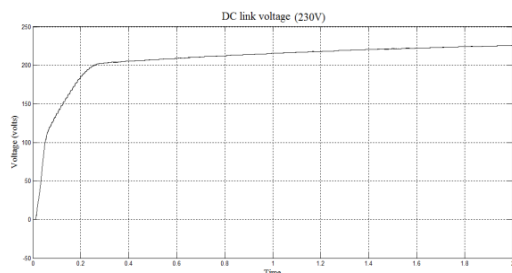


Figure.6 DC link voltage for 230V

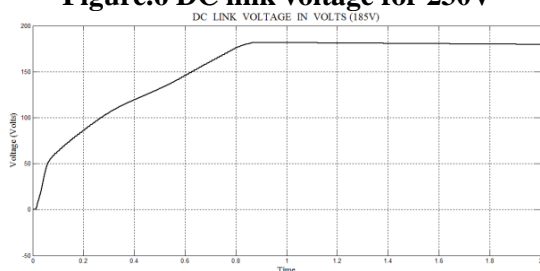


Figure.8 DC link voltage for 185V

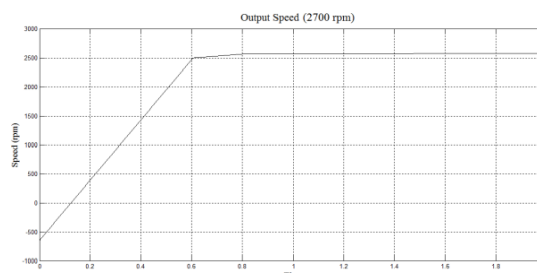


Figure.7 Output speed 2700rpm

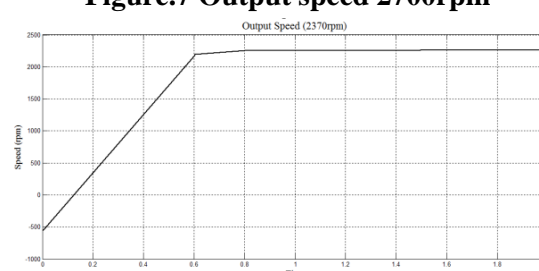


Figure.9 Output Speed of 2370rpm

Fig 6 to fig 9 shows the speeds of BLDC motor and their corresponding DC link voltages. These values are shown in the table I and these are simulated by using the MATLAB/simulink.

Table I

Performance of zeta converter fed BLDC motor for speed control.

Speed (rpm)	DC link Voltage (V)	Power Factor
1910	130	0.9979
2370	180	0.9982
2700	230	0.9986

6, CONCLUSION AND FUTUREWORK



A novel scheme of PFC and speed control of BLDC motor using a single voltage sensor is proposed for a fan load. A sensorless operation for the reduction of position sensor has been used. A single stage PFC converter system is designed for reducing the system cost and validated for the speed control with improved power quality at the AC mains for a wide range of speed. The performance of the proposed drive system has also been evaluated for varying the voltages and found satisfactory. The power quality indices for the speed control and power factor correction have been obtained within the limits. The future work of this paper is that zeta converter and BLDCM can be analyzed for PFC and speed control and also this type of converters can be applied for various speed control applications.

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