POWER FACTOR IMPROVEMENTS OF BRUSHLESS DC MOTOR USING ZETA CONVERTER

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ABSTRACT: This study deals with a reduced sensor configuration of a power factor correction (PFC) based zeta converter for brushless DC (BLDC) motor drive for low power applications. The speed of the BLDC motor is controlled by varying the dc-link voltage of the voltage source inverter (VSI) feeding BLDC motor drive. A low-frequency switching of the VSI is used for achieving the electronic commutation of BLDC motor for reduced switching losses. The PFC-based zeta converter is designed to operate in discontinuous inductor current mode; thus utilising a voltage follower approach which requires a single voltage sensor for dc-link voltage control and PFC operation. The proposed drive is designed to operate over a wide range of speed control with improved power quality at ac mains.

I. INTRODUCTION

Brushless DC (BLDC) motor is an ideal motor for low and medium power applications because of its high efficiency, high energy density, high torque/inertia ratio, low maintenance requirement and a wide range of speed control. It is a three phase synchronous motor with three phase windings on the stator and permanent magnets on the rotor. It is also known as electronically commutated motor as there are no mechanical brushes and commentator assembly; rather an electronic commutation based on rotor position sensed by Hall-Effect position sensor is used. It finds applications in a wide range of household appliances, industrial tools, heating, ventilation and air conditioning and many others [1–6]. The requirement of improved power quality at ac mains is becoming essential and increasingly important. A limit on the allowable harmonic current drawn from ac mains is imposed by international power quality standards such as IEC 61000-3-2 which in-turn limits the total harmonic distortion (THD) of supply current and power factor (PF) at ac mains. Hence, this recommends the use of improved power quality converters for achieving a unity PF (UPF) at ac mains with limited amount of harmonic distortion in the supply current. In a conventional scheme of Diode Bridge rectifier (DBR) with high value of dc-link capacitor fed BLDC motor drive, a high amount of harmonics current is drawn at ac mains. This combination draws peaky current and leads to a very highly distorted supply current and very low PF at ac mains.

A very high THD of supply current, that is, 65.9% and a very low PF, that is, 0.72 is achieved at ac mains, which is not under the acceptable limits of IEC-61000-3-2. Many single phase power factor correction (PFC) converters are reported in the literature for feeding the BLDC motor drive. Two-stage PFC converters have been in wide practice which use two different converters for PFC and dc-link voltage control. Generally, a boost converter is used of first stage for PFC followed by a second stage which depends on the type of application and voltage level required for that particular application. It requires higher number of components and thus has higher losses associated with it. Moreover, two different controllers for PFC and dc–dc conversion stage are required, which increase the system cost and complexity. Single-stage PFC converters, as the name suggests, require a single converter for performing both tasks of voltage control as well as PFC operation.

The most conventional scheme of feeding the BLDC motor is by using a PFC boost converter. A constant dc-link voltage is maintained at the dc-link capacitor of the voltage source inverter (VSI) feeding the BLDC motor. The speed control is achieved by using the pulse width modulation (PWM)-based switching of VSI, which has high switching losses corresponding to the PWM switching frequency. A concept of variable dc-link voltage for speed control of BLDC motor. This allows the operation of VSI in fundamental frequency switching for achieving an electronic commutation of BLDC motor. Based on this concept, a PFC-based single ended primary inductance converter fed BLDC motor drive. However, this scheme utilizes a higher number of sensors for controlling the stator current of the BLDC motor. Hence, this type of scheme finds application in higher end drives for precise speed control and is not suitable for low power, low cost household type appliances. Moreover, sensor reduction in a PFC-based BLDC motor drive is required for reducing the cost of complete drive. The PFC converter can be designed to operate in continuous inductor current mode (CICM) or discontinuous inductor current mode (DICM) operation. The PFC converter operating in CICM using a current multiplier approach requires sensing of dc-link voltage (Vdc), supply voltage (vs) and input current (iin). An inherent PFC is achieved in PFC converter operating in DICM using a voltage follower approach; and it requires sensing of dc-link voltage (Vdc), hence requiring a single voltage sensor

II. LITERATURE SURVEY

This investigation manages a diminished sensor design of a power factor rectification (PFC) based zeta converter for brushless DC (BLDC) engine drive for low power applications. The speed of the BLDC engine is controlled by fluctuating the dc-interface voltage of the voltage source inverter (VSI) nourishing BLDC engine drive. The test results have close concurrence with the recreated outcomes, which have appeared exact demonstrating of the proposed BLDC engine drive. The real issues in such drives are the voltage and current weights on the PFC converter switch, which restrains its activity for low power applications. Further work should be possible on decrease of these burdens utilizing delicate exchanging strategies for upgrading the working force go. Additionally, decrease of Hall-Effect position sensor can be utilized utilizing the sensorless control of BLDC engine drives for use of these drives in risky conditions. [1]

This paper shows a Zeta converter nourished power factor rectification (PFC) for high power light emanating diode (LED) driver. The application is focused for various string red-green-blue (RGB) LED drivers with lumen control. A heartbeat width adjustment (PWM) system is utilized for light yield control to accomplish required light without trading off the productivity. The Zeta converter is utilized to bolster a bi-flyback DC-DC converter which supplies capacity to the synchronous buck based consistent current exchanging controller and PMDC engine required for constrained cooling of LED module. The proposed converter intended for broken yield inductor current mode for PFC at widespread AC mains at whole load control. The created model of the proposed LED driver is tentatively checked. The power quality parameters of the proposed LED driver are assessed at evaluated and light load conditions for widespread AC mains (90-265V) with lumen control. The power quality parameters are estimated and found worthy scopes of global consonant standard. [2]

This paper displays a brushless DC (BLDC) engine drive with power factor adjustment (PFC) for low power and fast applications. In this examination, the speed of the BLDC engine is controlled by changing the DC interface voltage of the voltage source inverter (VSI). An epic PFC based Non-detached Zeta Fly-back converter working in spasmodic conduction mode (DCM) is utilized for controlling the DC connect voltage of the VSI by misusing single voltage sensor. Using the zeta converter and its significant property in lessening yield current swell and its naturally control factor amendment ability and interleaving fly-back converter to zeta and utilizing its high gain property, this converter can be a decent decision for interfacing BLDC engines drive. The MATLAB/SIMULINK condition is utilized to recreate the proposed model to accomplish a wide scope of speed control with close solidarity control factor at AC mains and enhanced PQ (Power Quality) in light of IEC 61000-3-2 standard. [3]

This paper shows an enlistment warmer (IH) with power factor revision (PFC) for residential acceptance warming applications. A half scaffold voltage bolstered arrangement resounding inverter (VFSRI) based IH is nourished from the front end PFC amended zeta converter. The PFC-zeta converter working in consistent inductor conduction mode (CICM) is utilized to control the DC interface voltage. The switch current worry of PFC-zeta converter is controlled by working zeta converter in CICM mode utilizing an entrenched interior current circle and external voltage circle approach. The PFC-zeta converter based voltage bolstered IH changes over transitional DC transport voltage to high recurrence (30 kHz) voltage reasonable for residential acceptance warming. A 2 kW PFC-zeta converter based IH is planned and its execution is mimicked in MATLAB with power quality records inside an IEC 61000-3-2 standard. [4]

This paper surveys different procedures for controlling a perpetual magnet DC brushless engine utilized for blower. Various driving techniques have been considered. The 120 degrees replacement, sensor-less back EMF recognition and the full control on the scaffold three-stage inverter circuit systems utilized in the engine driving plan are introduced. Speed control of the framework is accomplished by PWM strategy. PSIM programming is utilized for the plan of a model driver circuit. The control is effectively actualized by utilizing an ease microcontroller and IGBT module. [5]

The reason for this paper is to introduce an ideal proficiency control conspires for consistent power activity of stage decoupling (PD) PM brushless DC engine drives. The key is to adaptively modify the propelled conduction edge to limit the framework misfortunes for a given task point in the steady influence locale. The technique for consistent power task of PD PM brushless DC engine drives is exemplified utilizing a 5-stage 22-post PD PM brushless DC engine. In the areas that pursue, the recently created ideal effectiveness control procedure is then shown. At that point, in the wake of depicting the relating usage, both PC reenactment and exploratory outcomes are introduced, and a few ends are advertised. [6]

This paper manages different PWM exchanging methods for driving a 3-stage brushless DC engine. The simple based common and chip based ordinary PWM inspecting plans are exhibited. The 3-level PWM conspire is considered since it offers an enhanced quality supply and diminished consonant spectra. The reaction of the PM engine to these different driving plans is evaluated. [7]

This paper outlines how current plan programming bundles can be connected together to help the structure of high detail electrical machines where the warm appraising and execution is basic. First the product is tried against the deliberate execution of a real machine to approve precision of the connected electromagnetic and warm programming then different parameters are tried to delineate the key focuses in delivering an effective machine warm plan [8]

The utilization of brushless lasting magnet DC drive engines in dashing cruisers is talked about in this paper. The application prerequisites are featured and the attributes of the heap request and drive converter illustrated. The conceivable topologies of the machine are explored and a plan for an inside changeless magnet is created. This is a 6-shaft machine with 18 stator openings and loops of one stator tooth pitch. The execution expectations are advanced and these are gotten from structure programming. Cooling is crucial for these machines and this is quickly examined. [9]

The paper gives an account of the structure of a 20000 rpm, 3-stage brushless perpetual magnet DC engine for use in a contact welding unit, in which studs up to 3 mm breadth are welded by organizing the rotational speed of the engine with the power connected by a straight changeless magnet servo-actuator. The engine comprises of a stator having 3 teeth, which convey no overlapping windings, and a 2-post oppositely polarized sintered NdFeB magnet rotor. The air hole transition thickness dispersion is basically sinusoidal. The points of interest and burdens of such an engine topology for this and other rapid applications are talked about, and an ideal air hole measurement is determined. The impact of the stator tooth tip geometry on the waveform of the prompted EMF is explored by limited component investigation, and approved by estimations, while the benefits of overlaid silicon press and delicate attractive composite materials for the stator center are considered. [10]

III. PROPOSED SYSTEM

The speed of BLDC motor is controlled by varying the dc-link voltage of VSI. The PFC zeta converter is designed to operate in DICM; hence it acts as an inherent PF corrector. The complete operation of BLDC motor drive is realized using a single voltage sensor. An electronic commutation of BLDC motor is utilized for reducing the switching losses. The performance of the proposed drive is validated experimentally on a developed prototype. An improved power quality is achieved for a wide range of speed control with power quality indices within the limits of IEC 61000-3-2

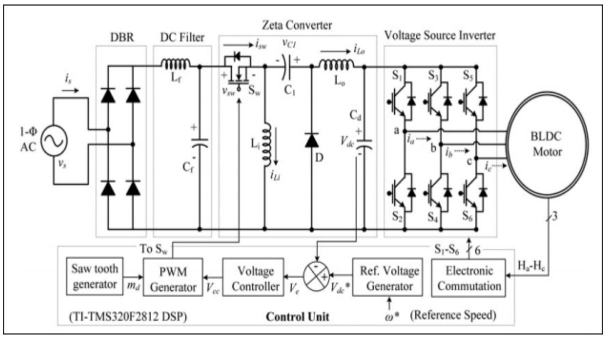
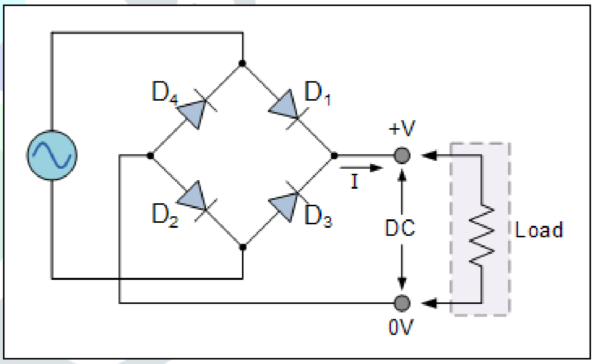


Fig 3.1 block diagram of proposed system

DBR (Diode Bridge Rectifier)

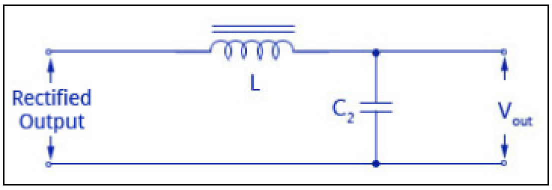
A Bridge rectifier is an Alternating Current (AC) to Direct Current (DC) converter that rectifies mains AC input to DC output. Bridge Rectifiers are widely used in power supplies that provide necessary DC voltage for the electronic components or devices. They can be constructed with four or more diodes or any other controlled solid state switches.

The four diodes labeled D1 to D4 are arranged in "series pairs" with only two diodes conducting current during each half cycle. During the positive half cycle of the supply, diodes D1 and D2 conduct in series while diodes D3 and D4 are reverse biased and the current flows through the load as shown below.



DC filter

The capacitor will reduce the ripple voltage, but causes the diode current to increase. This large current may damage the diode and may cause heating problem and decrease the efficiency of the filter. On the other hand, a simple series inductor reduces both the peak and effective values of the output current and output voltage. Then if we combine both the filter (L and C), a new filter called the L-C filter can be designed which will have a good efficiency, with restricted diode current and enough ripple removal factor .The voltage stabilizing action of shunt capacitor and the current smoothing action of series inductor filter can be combined to form a perfect practical filter circuit.



As appeared in the circuit outline over, the inductor L enables the dc to pass however limits the stream of air conditioning segments as its dc obstruction is little and air conditioning impedance is substantial. After a flag goes through the stifle, if there is any vacillation remaining the current, it will be completely avoided before it achieves the heap by the shunt capacitor in light of the fact that the estimation of Xc is a lot littler than Rload. The quantity of swells can be diminished to an extraordinary sum by making the estimation of XL more noteworthy than Xc at swell recurrence.

Zeta inverter

The PFC zeta converter is designed to operate in DICM, such that the current in input side inductor (iLi) becomes discontinuous, whereas the current in output side inductor (iLo) and the voltage across intermediate capacitor (vC1) remain in continuous conduction for a complete switching cycle. Figs. 3a–c shows the three different modes of operation of a PFC zeta converter in a complete switching cycle and its associated waveforms are shown in Fig. 3.2d. Three different modes of operation are as follows.

1) **Mode I (0 < t < t1):** As shown in Fig. 3.2a, when switch (Sw) is turned on, the input side inductor (Li) and the output side inductor (Lo) start charging. The intermediate capacitor (C1) discharges in this mode of operation and charges the dc-link capacitor as shown in Fig. 3.2 d. Therefore, the voltage across intermediate capacitor (VC1) decreases and the dc-link voltage (Vdc) increase in this mode of operation.
2) **Mode II (t2 <t t<t3):** This is the discontinuous conduction mode of operation, that is, the current in input inductor (iLi) reaches zero and becomes negative as shown in Fig. 2 c.
3) The dc-link capacitor supplies the required energy to the VSI feeding BLDC motor; hence the dc-link voltage (Vdc) starts decreasing in this mode of operation as shown in Fig. 2d.

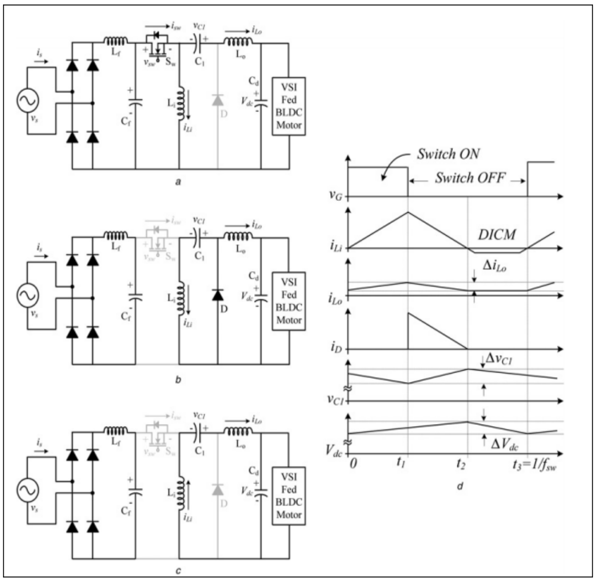


Fig 2 Different modes of operation of a PFC zeta converter in a complete switching cycle and its associated waveforms

Voltage source inverter

There are three types of inverter. An inverter circuit which creates an ac voltage (and current) from a dc voltage source is called a voltage source inverter (VSI). Similarly, the current source inverter (CSI) creates an ac current (and voltage) from a dc current source. A third converter type is called a resonant inverter. The load is a series resonant circuit that produces a high frequency sine-wave ac voltage. The dc voltage supplying the inverters is obtained from batteries or by rectifying the line voltage. Thus energy conversion sometimes takes place twice, from ac to dc then from dc to ac.

Voltage source inverters are used in ac motor drives and uninterruptible supply systems. They can be divided into two main categories.

- Pulse-Width-Modulated (PWM) inverters. The input dc supply voltage is constant. The inverter controls the magnitude and the frequency of the ac output voltage from the inverter. The synthesized output PWM voltage simplifies filtering and obtains a pure sine-wave curve.
- Square-wave inverters. The inverter has to control only the frequency of the output voltage. Therefore, the input dc voltage is controlled in order to control the magnitude of the ac output voltage.

CONCLUSION

A PFC zeta converter fed BLDC motor drive has been proposed for a wide range of speed control with UPF at ac mains. The speed of BLDC motor has been controlled by varying the dc-link voltage of VSI via the PFC zeta converter. The PFC zeta converter has been designed to operate in DICM, which required a voltage follower for dc-link voltage control. A single voltage sensor has been required for the complete drive, which makes it a cost-effective solution. Moreover, low-frequency switching pulses have been used for electronically commutating the BLDC motor which offers reduced switching losses in the VSI compared with conventional scheme of PWM-based switching of VSI.

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