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A Novel Zeta Converter with Pi Controller for Power Factor Correction in Induction Motor

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ABSTRACT

This study deals with a reduced sensor configuration of a power factor correction (PFC) based zeta converter for induction motor for low power applications. The speed of the Induction motor is controlled by varying the dc-link voltage of the voltage source inverter (VSI) feeding induction motor drive. A low-frequency switching of the VSI is used for achieving the electronic commutation of induction motor for reduced switching losses. The PFC-based zeta converter is designed to operate in discontinuous inductor current mode; thus utilizing 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 and the results are verified through numeric simulation using MAT Lab Simulink.

Keywords: Zeta converter, Cuk converter, voltage source inverter, power factor correction.

I. INTRODUCTION

Power electronics devices contribute with an important part of harmonics in all kind of application, such as power rectifiers, thyristor converters, and 3ϕ inverter. Even update PWM techniques used to control modern static converters such as machine drives, power factor compensators or active power filters do not produce perfect waveforms, which strongly depend on the semiconductors switching frequency. Voltage or current converters, as they generate discrete output waveforms, force the use of machine with special isolation and in some applications large inductance connected in series with the respective load in other words neither the voltage nor the current waveforms are as expected. It is well known that distorted voltages and current waveforms produce harmonic contamination, additional power losses and high frequency noise that can affect not only the power load but also the associated controllers. 3ϕ Induction is an asynchronous and self-starting motor and significantly improving the quality of the output voltage waveforms .They have a large torque to inertia ratio, high power density, high efficiency and better controllability[4]. Of this motor, preferred choice is the Induction motor for industries like Automotive, Aerospace, Consumer, Medical, Industrial Automation equipment and Instrumentation, because of its high torque, high efficiency, simplicity of control, and less maintenance. Zeta converter designed to operate on IM for Improve the PFC [2] Low frequency signals used for trigger the switches. Single sensor used for monitor the speed of the Induction motor. A single voltage sensor is used at the front-end converter for the control of dc link voltage for speed control of induction motor. The proposed drive is designed to operate over a wide range of speed control with improved power quality at ac mains. Use of a high switching frequency results in a instantaneous control of DC link voltage and effective PFC action along with additional advantage of reduced size transformer and filters. The switching device, switching losses and operating power level are major factors that decide optimum switching frequency. A metal oxide field effect transistor (MOSFET) is used as the switching device for the proposed PFC converter.

II. BLDC EMPLOYED WITH CUCK CONVERTER

CUK PFC converter used widely for feeding BLDC motor for improving power factor correction technique PWM is used for give the pulse to the switches.[1] DC link voltage is varied in the VSI side. Switches are operate with high frequency; due to these switching losses are very high at the switches. Cost of the system also high for using large number of sensors. CCM mode of PFC CUK converter is used, which requires 3 sensors for monitoring the 3-phase ac supply. This suited for only high power applications. This two stage topology is complex and results in higher cost and more losses.

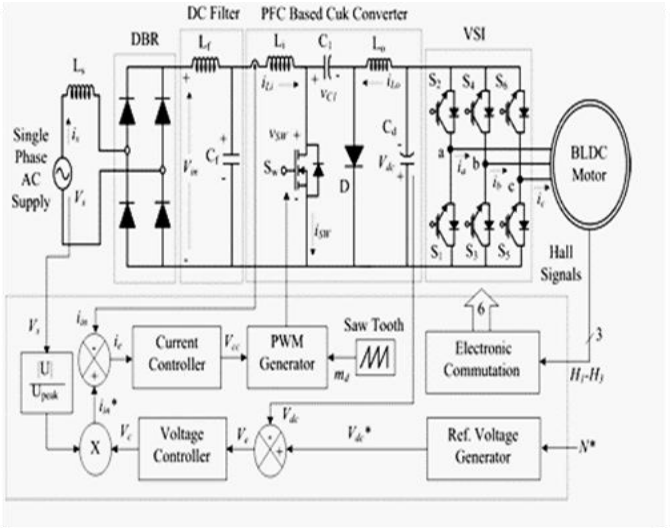

Figure 2. Zeta PFC converter fed BLDC drive

III. ZETA CONVERTER EMPLOYED WITH INDUCTION MOTOR

Proposed control scheme for PFC converter The prefered control scheme for improved PQ converter i.e. the Zeta converter as PFC converter is shown schematically in Fig. 3.1 which uses average current control with current multiplier approach. The Zeta converter controls the DC link voltage as well as performs PFC action by its duty ratio (D) at a constant switching frequency (fs). The PFC control scheme also employs an inner current loop and an outer voltage loop. The PFC can be achieved by tracking the average current to a reference value generated by multiplying the output of voltage error amplifier and a fraction of rectified input voltage. Fig.2.1. display the continuous current mode (CCM) operation of the proposed PFC converter. A proportional-integral (PI) controller which forms an integral part of the controller processes the voltage error resulting from the comparison of set voltage reference and sensed voltage at DC link. The output signal from PI controller is then multiplied with a unit template of input AC voltage and compared with DC current sensed after the DBR. The resultant current error is amplified and compared with a saw-tooth carrier wave of fixed frequency (fs) for generating the PWM pulses for controlling the MOSFET of PFC converter. The suggested PFC isolated Zeta converter is designed to drive an induction motor with an objective of PQ improvement at AC mains. The proposed scheme consists of a DBR, a Zeta converter and an output ripple filter.

The Zeta converter controls the DC link voltage at a given set reference value◌̇◌◌̤ . The design equations for DC link voltage of PFC converter is given by, Fig. 3.1. Converter-based classification of improved power quality converters 555 Athisankari et al. Power quality improvement in a induction motor drive using zeta converter as single stage PFC converter.

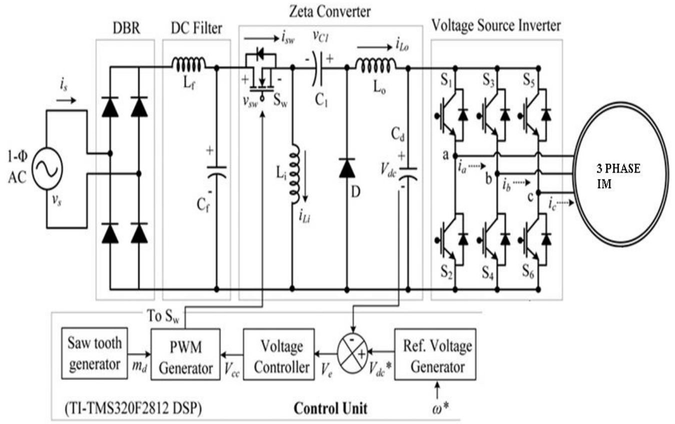

Figure 3. Zeta PFC converter fed IM drive

TECHNICAL DESCRIPTION:

A. SENSORLESS INDUCTION MOTOR DRIVE

The PFC converter and the sensor less induction motor drive are modelled for the proposed drive scheme. The control scheme of the PFC converter consists of following three blocks.[2]

B. Reference Voltage Generator:

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

C. Speed Controller:

An error of the Vdc* and Vdc is given to a PI (Proportional Integral) speed controller which generates a controlled output corresponding to the error signal.

The error voltage Veat any instant of time k is as;

$$Ve(k) = Vdc^*(k) - Vdc(k)$$

and the output Vc(k) of the PI controller is given by,

$$Vc(k) = Vc(k-1) + Kp.(Ve(k) - Ve(k-1)) + Ki.Ve(k)$$

Where Kp is the proportional gain and Ki is the integral gain constant.

D. PWM Generator:

The output of the PI controller V_c 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 as shown in Fig. 3 and PWM is generated as; If- $m_d(t) < V_c(t)$ then S=1 else S=0 (10) where S denotes the switching signals as 1 and 0 for MOSFET to switch on and off respectively.

IV. CONTROLLING TECHNIQUE EXPLANATION

Sensor less operation of induction motor drive:

To eliminate the requirement of Hall Effect position sensor for the overall cost reduction of the PFC drive system, a sensor less approach is used. Many sensor less techniques are available in the literature for the estimation of position of the rotor . In this paper, line back emf is used for position detection using a ZCD (Zero Crossing Detector). The complete operation of sensor less Induction motor is classified into open loop starting, switching from starting to sensor less mode and finally the sensor less operation.

A. Open Loop Starting:

In open loop startup technique, a rotating field at the stator is given with gradually increasing magnitude and frequency such that it can overcome the rotor inertia and friction at standstill position and begins rotating at low speed. The voltage applied should be such that the current should not exceed the maximum current rating of the Induction motor.

B. Switching from Starting to Sensor less Mode

When the rotor rotates above a certain speed in the open loop starting, and proper estimation of the virtual Hall Effect position signals are obtained then the motor is switched from open loop starting mode to sensor less mode of operation.

C. Sensor less Operation:

There are numerous methods for the estimation of rotor position. A basic approach of determining line voltage is by the measurement of phase voltage with the virtual ground and then calculating the line voltage is used. A ZCD detects the zero crossing of the voltage and then the virtual Hall signals for electronic commutation are generated. Fig. 5 shows the starting, switching from starting to sensor less mode and the sensor less operation of the Induction motor drive. As shown in this figure the estimated virtual Hall Effect rotor position signal and the actual hall signals are overlapping showing the accurate detection of position using the sensor less algorithm. Moreover, the stator current is much less than the maximum current rating of motor during open loop starting and a smooth transition from open loop starting to sensor less mode is also achieved.

D. ZETA CONVERTER

Similar to the SEPIC DC/DC converter topology, the ZETA converter topology provides a positive output voltage from an input voltage that varies above and below the output voltage. The ZETA converter also needs two inductors and a series capacitor, sometimes called a flying capacitor. Unlike the SEPIC converter, which is configured with a standard boost converter, the ZETA converter is configured from a buck controller that drives a high-side PMOSFET. The ZETA converter is another option for regulating an unregulated input-power supply, like a low-cost wall wart. To minimize board space, a coupled inductor can be used. This article explains how to design a ZETA converter running in continuous-conduction mode (CCM) with a coupled inductor.

V. BASIC OPERATION

A simple circuit diagram of a ZETA converter, consisting of an input capacitor, CIN; an output capacitor, COUT; coupled inductors L1a and L1b; an AC coupling capacitor, CC; a power PMOSFET, Q1; and a diode, D1. The ZETA converter operating in CCM when Q1 is on and when Q1 is off. To understand the voltages at the various circuit nodes, it is important to analyze the circuit at DC when both switches are off and not switching. Capacitor CC will be in parallel with COUT, so CC is charged to the output voltage, VOUT, during steady-state CCM. The voltage across L1a and L1b during CCM operation. When Q1 is off, the voltage across L1b must be VOUT since it is in parallel with COUT. Since COUT is charged to VOUT, the voltage across Q1 when Q1 is off is VIN + VOUT; therefore the voltage across L1a is –VOUT relative to the drain of Q1. When Q1 is on, capacitor CC, charged to VOUT, is connected in series with L1b; so the voltage across L1b is +VIN, and diode D1 sees VIN + VOUT.

The currents flowing through various circuit components are shown in Figure. When Q1 is on, energy from the input supply is being stored in L1a, L1b, and CC. L1b also provides IOUT. When Q1 turns off, L1a's cur- rent continues to flow from current provided by CC, and L1b again provides IOUT.

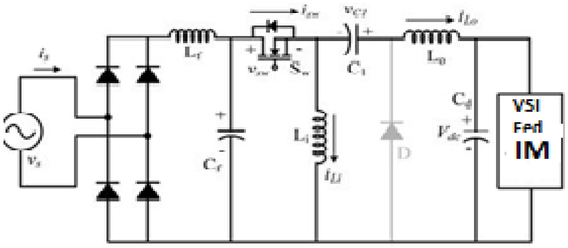

Fig.5.1. Mode 0 Operation

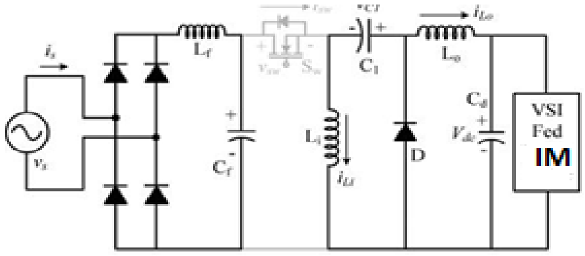

Fig.5.2. Mode 1 Operation

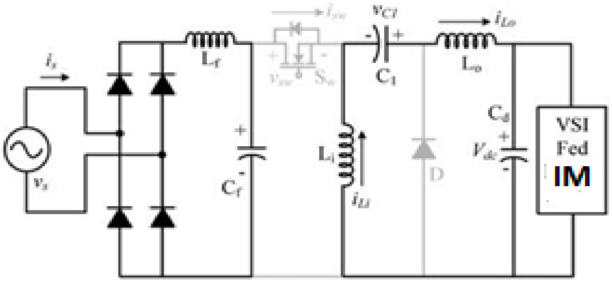

Fig.5.3. Mode 2 Operation

Duty cycle

Assuming 100% efficiency, the duty cycle, D, for a ZETA converter operating in CCM is given by

$$D = \frac{\text{OUTPUT VOLTAGE}}{\text{INPUT VOLTAGE} - \text{OUTPUT VOLTAGE}}$$

This can be rewritten as

$$\frac{D}{1-D} = \frac{I_{IN}}{I_{OUT}} = \frac{V_{OUT}}{V_{IN}}$$

Dmax occurs at VIN(min), and Dmin occurs at VIN(max).

VI. SIMULATION WAVEFORMS

A. Input Voltage Waveform

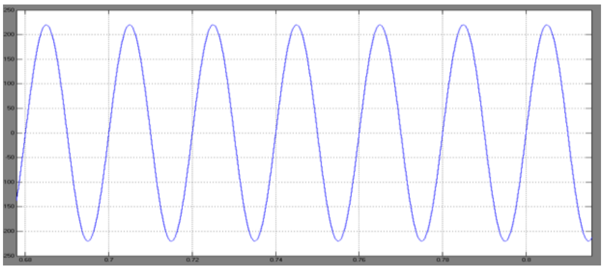

Fig.6.1.Input Voltage Waveform

B. Gate Pulse

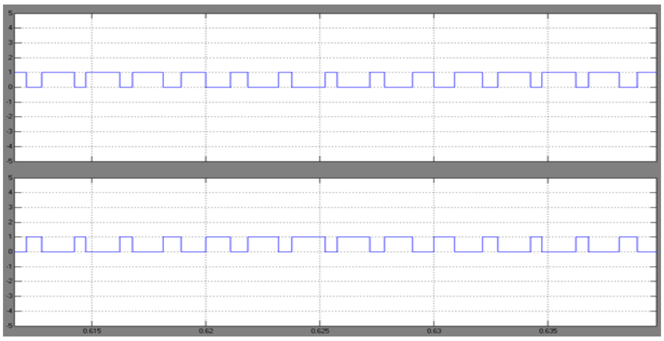

Fig.6.2. Gate Pulses

C. **Output Voltage And Current Waveform**

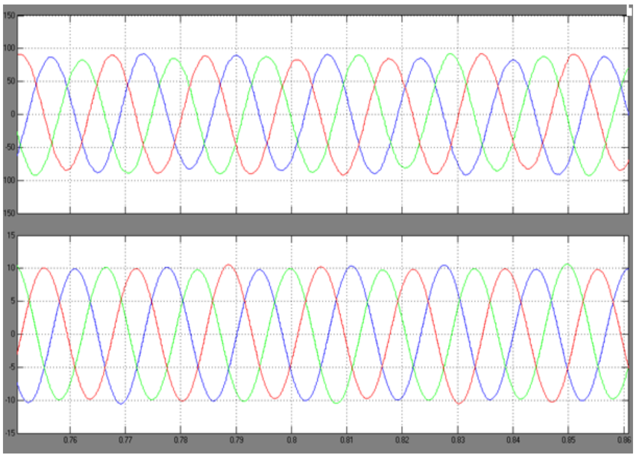

Fig.6.3.Output Voltage and Current Waveform

D. **Induction Motor Output Waveforms**

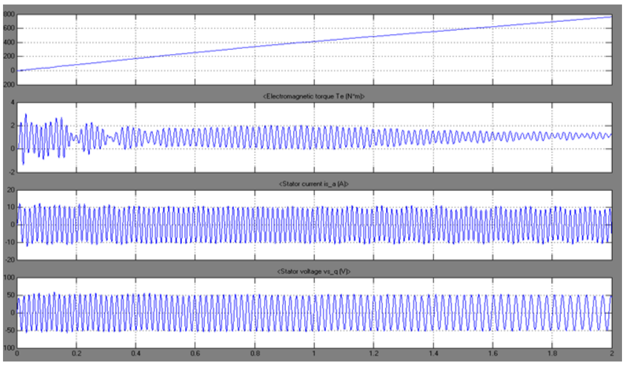

Fig.6.4. Induction Motor Output Waveforms

VII. RESULTS AND CONCLUSION

A PFC zeta converter fed induction motor drive has been proposed for a wide range of speed control with UPF at ac mains. Moreover, low-frequency switching pulses have been used for induction motor which offers reduced switching losses in the VSI compared with conventional scheme of PWM-based switching of VSI. The proposed drive has been designed for achieving an improved power quality at ac mains for a wide range.

VII. REFERENCES

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