



## Interharmonic Mitigation Using Boost Converter In Variable Speed Drives

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**Abstract**—Voltage source inverter (VSI) fed induction motors are widely used in industries. It injects significant amount of harmonics and interharmonics into the supply system. Interharmonics are components whose frequencies are not an integer multiple of the fundamental frequency. Interharmonics are injected into the supply when two different frequency systems are interlinked or due to load unbalance. In this work motor load unbalance is considered and a boost converter is designed to mitigate interharmonics. Simulation is carried out in PSIM and the superiority of the proposed method is discussed.

**Keywords**—Interharmonic mitigation, boost converter, Variable Frequency Drive, load unbalance

### I. INTRODUCTION

A variable frequency drive is considered as a frequency converter which converts input voltage at the utility frequency to a voltage at the drive operating frequency. Among the commonly recognized sources of Interharmonics, pulse-width-modulated voltage source inverter fed induction motors are popular [2]. VSI fed induction motor has a front end rectifier which converts input ac into unregulated dc. In general diode bridge rectifiers are used which are simple and highly reliable [6]. In the dc link a large capacitor is connected to reduce ripples in the dc voltage. After the rectifier, a PWM inverter converts dc voltage into ac voltage of variable magnitude and frequency [4]. As the input and the drive operating frequencies are different, interharmonics are introduced in the utility current. These interharmonics have undesirable effects such as overheating, overstressing of capacitor banks, abnormal operation of electronic relays, telephone interference, light flicker even though its magnitude is less [3], [5]. Also the interharmonic frequency is not constant and it is varying with the load operating frequency. Therefore it is difficult to eliminate using passive filters that are tuned at harmonic frequencies.

This work considers load current unbalance by connecting an inductance in series with the phase winding [1]. The effect of load imbalance is analyzed and a boost converter is designed to mitigate the interharmonics. The proposed method is simulated in PSIM and the results are discussed.

### II. INTERHARMONICS DUE TO LOAD UNBALANCE

An inductor of 0.125mH is connected in series with one of the phase windings to analyse motor current unbalance. Due to this motor current unbalance harmonic is transferred from the motor to the dc link which is transferred to the rectifier input side and appears as harmonic and interharmonic in the supply side.

#### *Harmonic Transfer to the DC link from the Inverter*

The inverter input current is given by

$$i_{inv} = S_{ui} i_{ui} + S_{vi} i_{vi} + S_{wi} i_{wi} \quad (2)$$

$$i_{inv} = I_{dc} + \sqrt{2} I_{inv} \cos(2\omega_{out} t + \phi_n) \quad (3)$$

$$\text{Where } I_{dc} = \frac{3}{4} m_i \sqrt{2} I_p \cos \phi_p \quad (4)$$

and  $S_{ui}$ ,  $S_{vi}$ ,  $S_{wi}$  are inverter switching functions.

$I_{dc}$  component results in active power transfer. The component  $I_{inv}$  is responsible for the change of the inverter dc link current with two times the output frequency.

### Harmonic Transfer to the Rectifier side DC link

The disturbance in the inverter side dc link is transferred to the dc link of rectifier. The disturbed current at the dc link of the rectifier is given by

$$i_{rect} = I_{dc} + \sqrt{2} I_{rect} \cos(2\omega_{out} t + \phi) \quad (5)$$

Where

$$I_{rect} = k_{dclink} I_{inv} \quad (6)$$

Where  $k_{dclink}$  is the dc link current magnification factor. This magnification occurs at the dc link due to parallel resonance [1]. As the motor output frequency is varied from 0 to  $f_{out}$  the rectifier side dc link current fluctuates with the frequency ranging from 0 to  $2 f_{out}$ .

### Harmonic Transfer through the rectifier

For this analysis, the rectifier switching functions are considered. The rectifier is assumed to conduct continuously. The input currents of the rectifier considering the switching function are given by

$$\begin{aligned} i_{ar} &= S_{ar} i_{rect} \\ i_{br} &= S_{br} i_{rect} \\ i_{cr} &= S_{cr} i_{rect} \end{aligned} \quad (7)$$

The switching functions of the rectifier are approximated to their fundamental components as follows

$$\begin{aligned} S_{ar} &= A_1 \cos(\omega_{in} t) \\ S_{br} &= A_1 \cos\left(\omega_{in} t - \frac{2\pi}{3}\right) \\ S_{cr} &= A_1 \cos\left(\omega_{in} t + \frac{2\pi}{3}\right) \end{aligned} \quad (8)$$

Where  $A_1$  is the amplitude of the fundamental harmonic component and it is given by

$$A_1 = \frac{2\sqrt{3}}{\pi} \quad (9)$$

Thus the derived input current of the rectifier for phase A is

$$\begin{aligned} i_{ar} &= \sqrt{2} I_1 \cos(\omega_{in} t + \phi_{in}) + \\ &+ \sqrt{2} I_H \cos((2\omega_{out} t + \omega_{in} t) + \phi) \\ &+ \sqrt{2} I_H \cos((2\omega_{out} t - \omega_{in} t) + \phi) \end{aligned} \quad (10)$$

Where

$$I_1 = A_1 I_{dc} \quad (11)$$

$$I_H = \frac{1}{2} A_1 I_{rect} \quad (12)$$

Thus the unbalance in the motor current is propagated to the supply with two components which are symmetrical at  $2f_{out} \pm f_{in}$ .

### III. SIMULATION

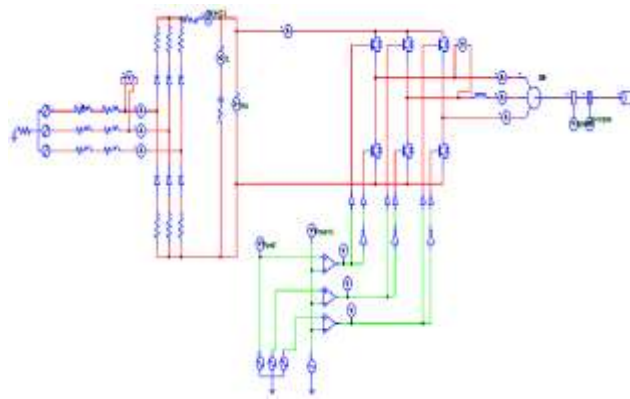
#### *variable frequency choke with ac dreive*

Variable frequency drive is simulated in PSIM considering load unbalance with ac choke in the rectifier input side. The inductor value is chosen by trial and error method and is equal to  $200\mu\text{H}$ . The range of the inductance is between  $200\mu\text{H}$  to  $1\text{mH}$ . Increasing inductance value beyond this value results in voltage distortions. The diagram of VFD is shown in Fig.2 and is simulated for the drive operating frequency of  $40\text{Hz}$ .

Simulation is carried out using the parameters listed in Table I.

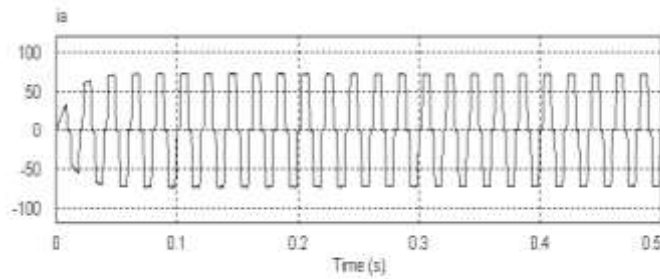
*Table I*

AC source		Induction Motor	
Voltage	400V	Rated Power	20kW
Frequency	50Hz	Rated Voltage	400V
Resistance	$8\text{m}\Omega$	Stator Resistance	$0.494\Omega$
Inductance	$0.5\text{mH}$	Stator Leakage Inductance	$0.000139\text{H}$
DC Link	Rotor Resistance		$0.356\Omega$
Resistance	$3.5\text{m}\Omega$	Rotor Leakage Inductance	$0.00074\text{H}$
Inductance	$0.1\text{H}$	Pairs of Poles	3
Capacitance	$0.0005\text{F}$	Motor Operating Frequency	$40\text{Hz}$ to $50\text{Hz}$

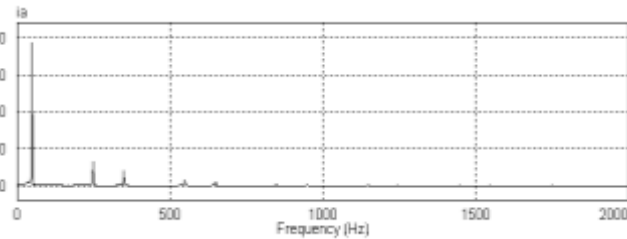


*Fig.2*

The rectifier input current and its spectrum analysed using FFT are shown in Fig.3



(a) Rectifier input current



(b) Rectifier input current spectrum

The rectifier input current spectrum is analyzed for Interharmonics. From equation (10), the rectifier input current has Interharmonics at frequencies of  $2f_{out} \pm f_{in}$  ( $f_{in}$  – supply frequency,  $f_{out}$  – drive operating frequency). When the drive operating frequency is 40Hz, Interharmonics occur at frequencies of 130Hz and 30Hz. The magnitude of the interharmonic components are measured and tabulated in table II.

Table II

Interharmonic frequency	Interharmonic magnitude as % of fundamental
30Hz	1.8
130Hz	0.366

**Variable frequency drive with boost converter**

The main objective of the boost converter[7] in the dc link is to eliminate Interharmonics in the rectifier input side. The general block diagram of the proposed system is shown in Fig.3.

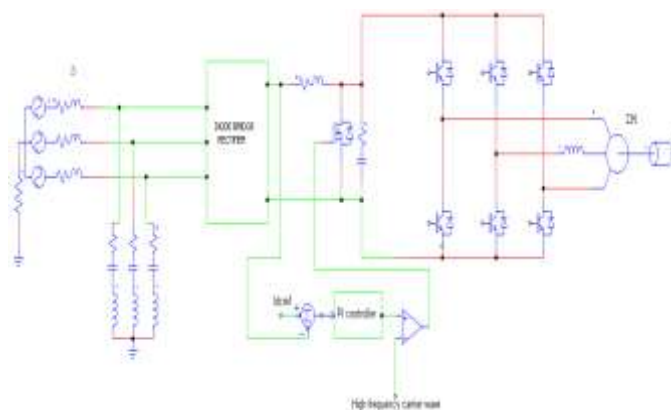
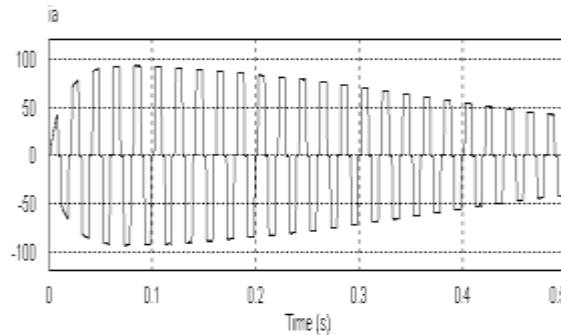
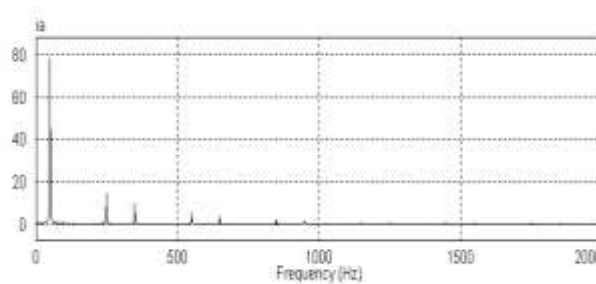


Fig.3

The single switch boost converter topology is employed which has an LC input filter. The boost switch is turned on at a constant frequency. The dc link current is subtracted from the reference dc current and the error signal after the PI controller is compared with the high frequency carrier signal to obtain the gate pulse for the boost switch. The proposed system is simulated in PSIM. The rectifier input current and its spectrum are shown in Fig.4 for the drive operating frequency of 40Hz.



(a) Rectifier input current



(b) Rectifier input current spectrum  
 Fig.4

When the drive operating frequency is 40Hz, the interharmonic frequencies are at 30Hz and 130Hz according to the relation  $2f_{out} \pm f_{in}$ . The magnitude of the interharmonic components is measure and tabulated in Table III.

Table III

Interharmonic frequency	Interharmonic magnitude as % of fundamental
30Hz	0.93
130Hz	0.2

The interharmonic magnitudes are greatly reduced by the proposed method. The magnitude of the interharmonic components obtained using both the methods are compared and is shown in Fig.5 which clearly shows the superiority of the proposed method.

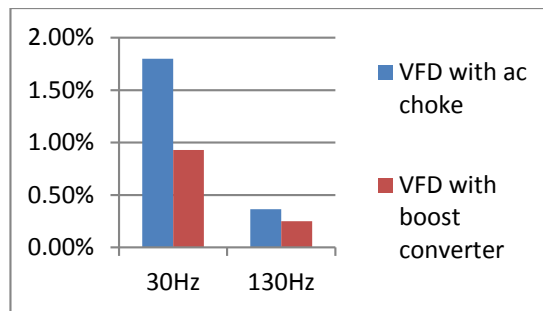


Fig.5

#### IV.CONCLUSION

In this work, interharmonic in the supply side of VSI fed induction motor due to motor current unbalance is analyzed. First VFD with ac choke in the input side of the rectifier is simulated using PSIM. Then VFD with a single switch boost converter in the dc link is simulated using PSIM. The magnitude of the interharmonic obtained in these two methods are compared which shows the superiority of the proposed method.

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