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Research Article

Effect of DC Link Fluctuations on Harmonic Spreading Effect in Voltage Source Inverter Fed Three Phase Induction Motor Drives

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Abstract: The aim of the study is to analyze the effect of DC link fluctuations on the output voltage of the inverter. Voltage Source Inverters (VSI) plays a dominant role in the industrial world. Most of the industries use rectifiers to convert single phase AC supply to DC supply. DC supply is fed to the Voltage Source Inverter (VSI) through a DC link capacitor. The capacitor decides the quality of output fed to the Voltage Source Inverter. Six pulses are given to the Voltage Source Inverter by means of MCBRCPWM (Multiple Carrier Based Random Carrier Pulse Width Modulation) technique. The output of Voltage Source Inverter is fed to a three phase squirrel cage induction motor. The investigation of MCBRCPWM with different capacitor values provided in the DC link has been effectively discussed. The results of harmonic spectra and Total Harmonic Distortion (THD) are given in the paper. Simulation results prove that as the value of capacitor increases, the evaluation parameters such as Total Harmonic distortion, Fundamental Voltage and Harmonic Spread Factor (HSF) are improved.

Keywords: DC link, harmonic spread factor, random pulse width modulation, voltage source inverters

INTRODUCTION

The study on VSI working with fluctuating input has been carried out by few researchers. The dc link voltage fluctuation problem is a serious problem to be considered for an inverter system which utilizes a single phase AC source as proposed by Enjeti and Shireen (1990). Single-phase AC-DC converter combined with a three-phase DC-AC inverter has been widely used in electrical drive systems. The DC-link voltage contains a ripple component twice than that of power line frequency because of the single-phase converter configuration. Beat phenomenon of the motor current usually occurs, when fed by a fluctuating DC-link voltage. This causes torque ripple and noise in the motor, when the electric frequency of the motor is found to be near the DC-link ripple frequency as given by Habetler and Divan (1991).

A new technique for generating pulse width modulated waveforms that simultaneously eliminates harmonics and rejects DC-link ripple is proposed by Klima *et al*. (2008). By rejecting the lower-order harmonics generated by the DC-link voltage ripple, high-quality inverter output voltage is guaranteed. The modulator in the proposed PWM technique is altered by a feed forward approach. In order to improve the compensation performance, a repetitive dc link voltage predictor is proposed by Kim *et al*. (2009). The repetitiveness of the dc link ripple and prediction of the average value of the dc link voltage in the next switching period is performed. The method is proved to reduce the beat current by six or up to seven times.

The dc-link voltage variation under voltage sag conditions and its dependence on dc-link inductance, source impedance and output load are discussed by Ouyang *et al*. (2011). Three phase VSI fed PWM inverter under the dc link ripple voltage component for induction motor drive has been detailed by Gou *et al*. (2012). Various Random pulse width modulation techniques have been proposed to reduce the acoustic noise, vibration and other radio interferences as presented by Maruthupandi *et al*. (2013) and Jung *et al*. (2014). The competent PWM strategies applied to VSI fed drives in achieving their objectives are proposed by Dur´an-G´omez *et al*. (2015).

It is well understood from the literatures, that the harmonic spreading effect of the VSI under dc input fluctuations has not been effectively addressed. This study proposes a technique to effectively prove the effectiveness of the MCBRCPWM in distorted input conditions.

MATERIALS AND METHODS

The three phase VSI topology shown in Fig. 1 consists of DC voltage source, dc link filter (capacitor)

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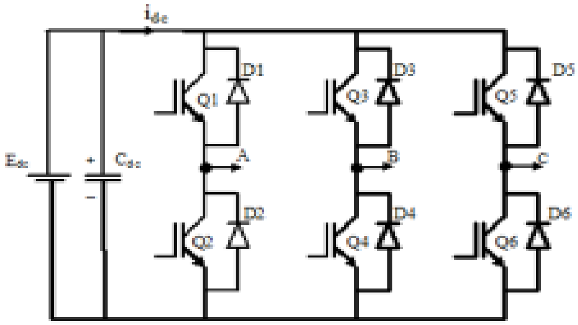

Fig. 1: Three-phase VSI topology

Table 1: Induction motor specifications

Parameter	Value
Power (P)	0.75 kW
Line- Line voltage (V_L)	415 V
Frequency (f)	50 Hz
Stator resistance (R_s)	1.435 Ω
Stator inductance (L_s)	0.005839 H
Rotor resistance (R_r)	1.395 Ω
Rotor inductance (L_r)	0.005839 H
Inertia (J)	0.0131 Kgm^2
Friction factor	0.0029 Nms
Pole pairs	2
Stator connection	Star

and Voltage Source Inverter (VSI). DC voltage is given to the dc link capacitor and the fluctuating DC is obtained. The ripple present in the dc link is removed by the filtering capacitor before feeding to the VSI. The effectiveness of filtering technique depends on the value of the capacitor used.

E_{dc} is the dc supply voltage. C_{dc} is the dc capacitor link provided in the three phase voltage source inverter. Q_1 to Q_6 are the six switches (IGBT's-Insulated Gate Bipolar Transistors) used for high switching frequency operation. D_1 to D_6 are the freewheeling diodes. A, B and C are the three phase outputs of Voltage Source Inverter. The inverter output can be connected to an external 3 phase AC drive such as an induction motor. DC link fluctuations and its effect on the three phase voltage source inverter are proposed in this study.

Proposed MCBRCPWM is a pure extension of Random Carrier Pulse Width Modulation (RCPWM) strategy and is detailed by Sivarani *et al*. (2016).

RESULTS AND DISCUSSION

The simulation study is performed in MATLAB/Simulink software. A three-phase VSI inverter with three-phase 0.75 kW Squirrel Cage Induction Motor is considered. The specifications of the induction motor are given in Table 1. The input dc voltage (Vdc) is 415V and the output frequency is 50 Hz. The switching frequency of SPWM is 3 kHz, while the RPWM employs ±3kHz. The complete MATLAB-Simulink schematization of the developed MCBRCPWM is screen captured in Fig. 2. The ODE Solver ode23tb is considered for the simulation study.

Figure 2 shows the simulink implementation of the proposed MCBRCPWM working with fluctuating DC. A diode bridge rectifier is used to convert single phase AC supply to DC supply. A DC link capacitor is placed in parallel with the output of the rectifier. This is in turning coupled with the three phase Voltage Source Inverter. The output of VSI drives the three phase Induction Motor.

Figure 3 shows the line to line voltage of the inverter output for modulation index Ma = 0.8 with capacitor C = 3300 micro Farad.

The carrier waveforms and the corresponding pulses to be fed to the switches of VSI are shown in

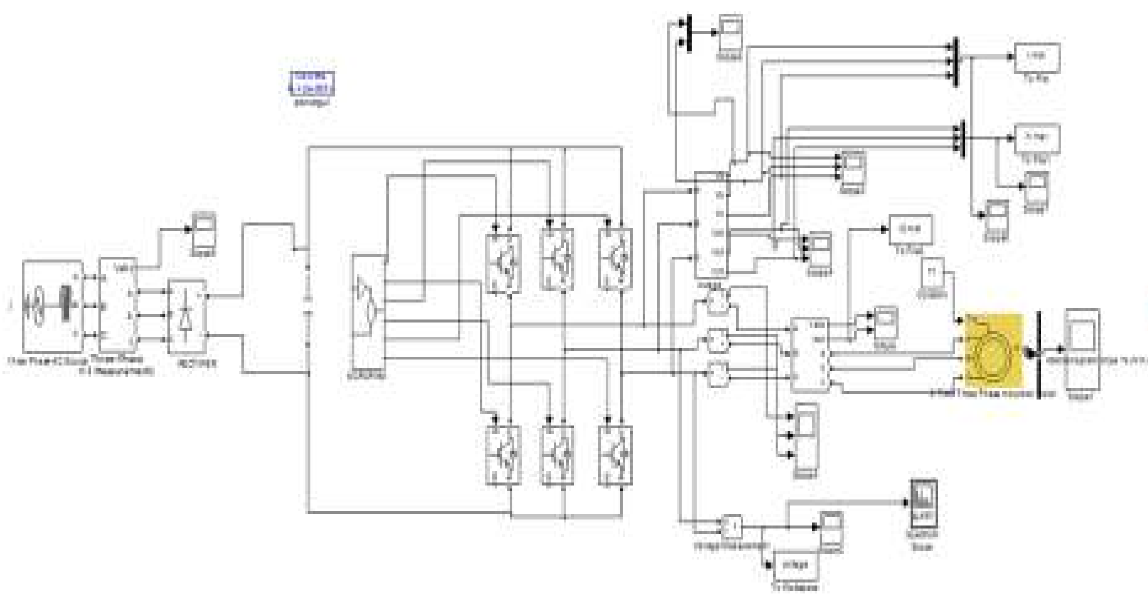

Fig. 2: Simulink implementation of MCBRCPWM under fluctuating DC link

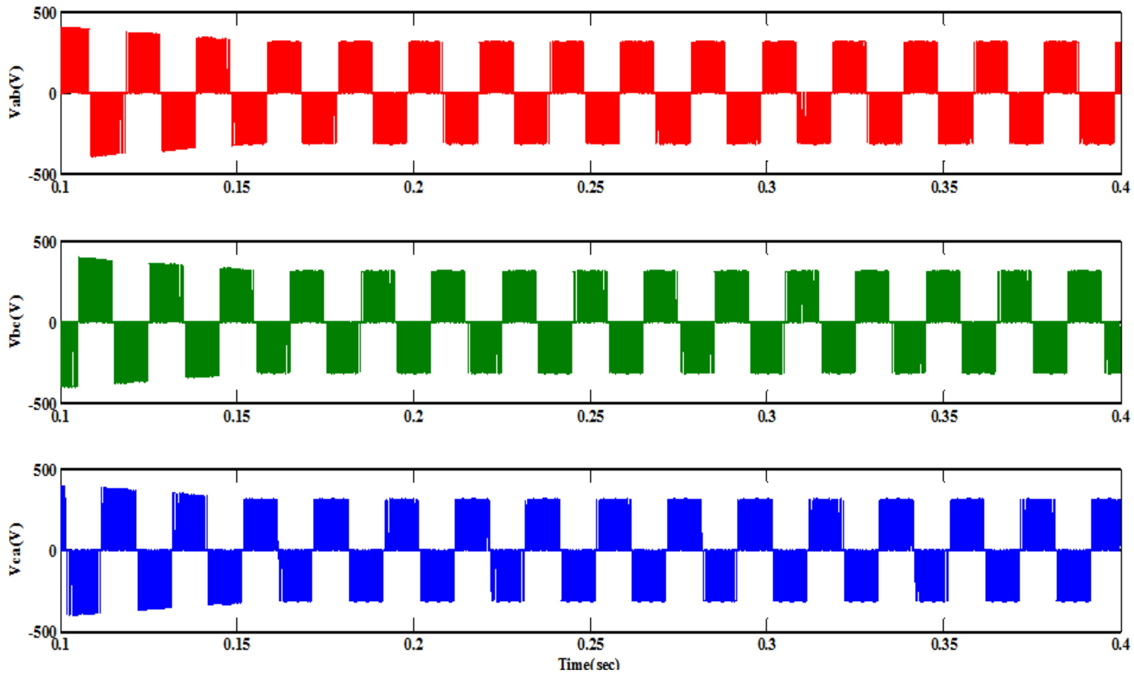

Fig. 3: Phase-to-phase voltage waveforms (DC Link-MCBRCPWM)

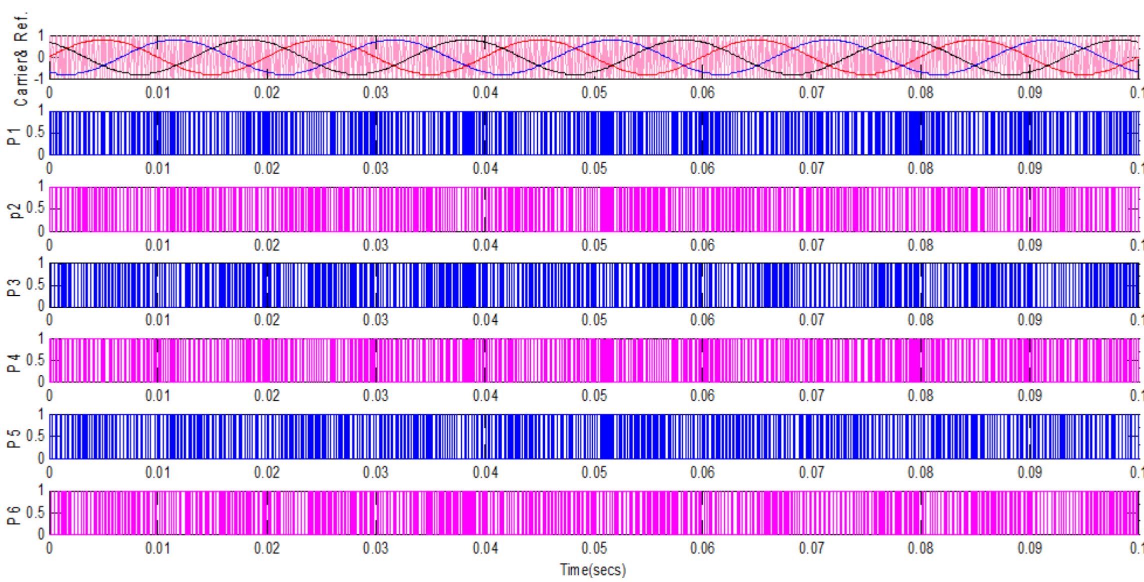

Fig. 4: Carrier waveforms and outputs of six pulses (DC Link-MCBRCPWM)

Table 2: Performance comparison of MCBRCPWM with different capacitors

	V_0				THD				HSF			
M_a	22µF	33µF	330µF	2200µF	22µF	33µF	330µF	2200µF	22µF	33µF	330µF	2200µF
0.2	74.1	72.9	75.8	75.3	250.7	260.2	249.4	241.4	5.9	5.9	5.8	5.1
0.4	136.4	133.4	135.6	138.2	175.3	183.5	174.8	169.4	5.4	5.4	4.9	4.8
0.6	203.7	207.3	209.9	211.9	128.9	131.9	124.3	120.8	5.1	5.12	4.4	4.2
0.8	280.6	281.7	284.4	286.1	92.60	92.6	92.30	89.90	4.5	4.13	3.9	3.8
1.0	365.3	365.2	371.1	371.5	72.00	72.40	65.90	67.50	4.3	4.01	3.7	3.7
1.2	386.9	394.7	397.5	399.0	62.50	68.80	59.80	56.20	4.1	3.9	3.3	3.3

Fig. 4. Figure 5 shows the corresponding line currents of the inverter output.

FFT analysis of line to line voltage waveform is carried out and shown in Fig. 6. A considerable spread

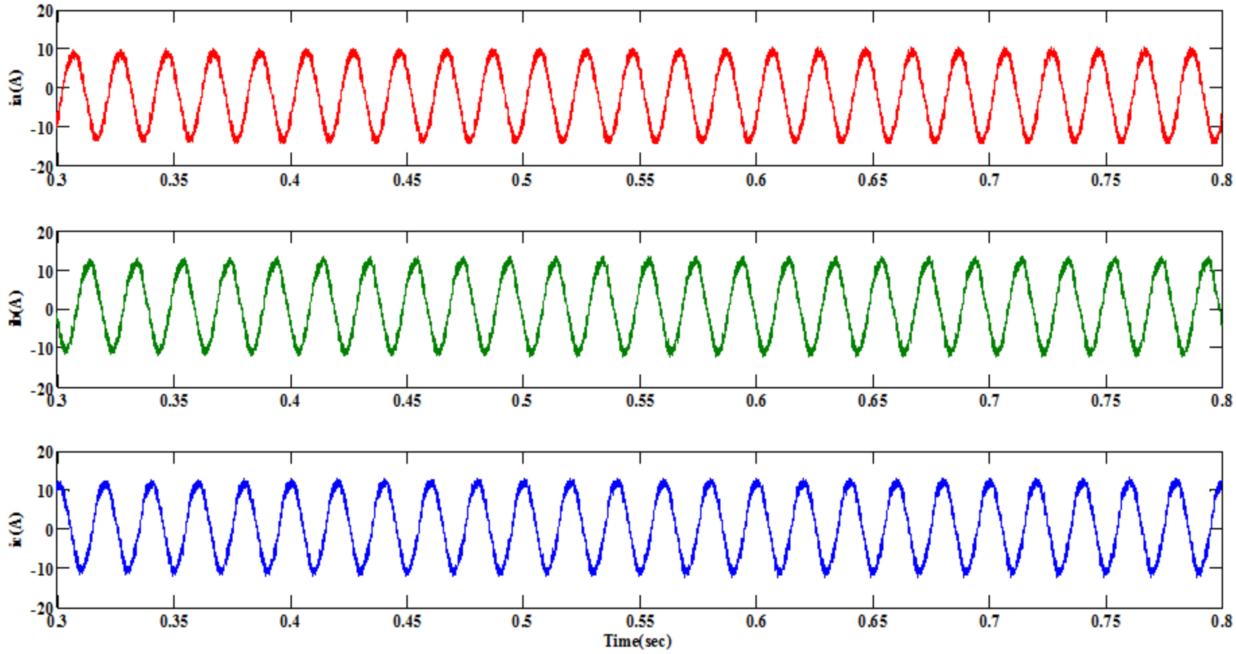

Fig. 5: Line current waveforms for three phases (DC Link–MCBRCPWM)

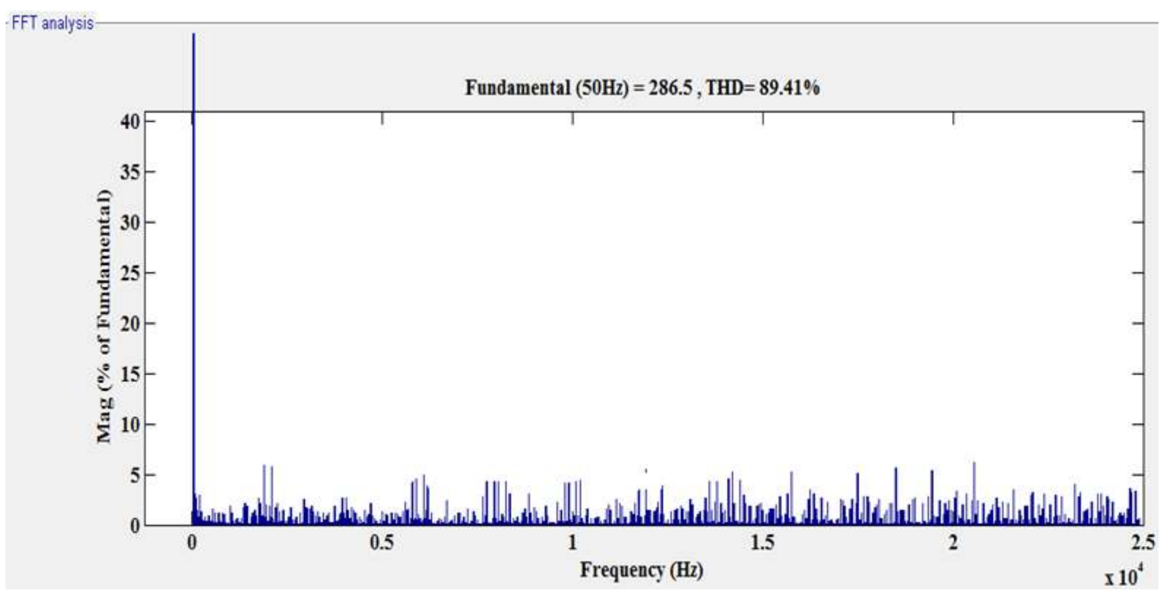

Fig. 6: FFT analysis

in spectrum is noticed. Moreover the magnitude of lower order harmonics also gets reduced.

Table 2 shows the comparison performance of MCBRCPWM under fluctuating DC conditions for modulation index Ma = 0.8. It shows a remarkable improvement in Harmonic Spread Factor (HSF) as the value of capacitance increases. Even though the DC link fluctuates due to supply line variations, the proposed MCBRCPWM is able to maintain HSF at a low value. Fundamental component is also increased, but Total Harmonic Distortion (THD) remains almost the same.

CONCLUSION

Random Carrier PWM developed for VSI with constant DC input does not yield better results, as input DC voltage becomes fluctuating. The Fast Fourier Transform (FFT) harmonics spectrum is studied for various modulation index values. The tabulated results such as fundamental magnitude, THD and HSF show the improved performance of MCBRCPWM compared to RCPWM. The results illustrate that, even for high D fluctuations, the proposed scheme yields satisfactory performance. Because the spectral peaks are spread over the entire frequency range, use of filters is not necessary to eliminate the lower order harmonics.

Conflict of interest: Authors declare that there is no potential conflict of interest in publication of the manuscript.

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