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Performance of Matrix Converter and Direct Current Link Converter Fed Induction Motor Drive System

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ABSTRACT

This paper presents the comparison of performance between matrix converter and conventional DC-link converter fed induction motor drive system. The output current from conventional converter contains odd harmonic component which produces additional losses in drive causes de-rating and torque pulsation of motor. The simulated result is compared with conventional converter to show that proposed system is better than conventional system. This paper also presents modeling and simulation of matrix and conventional converter fed induction motor drive system using MATLAB/SIMULINK software.

Keywords: *Conventional DC-link converter, Matrix converter, Switching strategy, Modeling, Total Harmonic Distortion Analysis, Torque Pulsation.*

1. INTRODUCTION

Induction motor is such popularity takes place due to its simple construction and robustness. Since speed-torque characteristic of IM depends on supply frequency and applied voltage.

Converter usually has functions of voltage regulation, protection and drive control. Main function of converter is to generate controllable sinusoidal AC outputs in terms of variable magnitude and frequency from fixed AC supply.

The main efforts which elaborates converter are usually directed to the increasing of converter efficiency and improving the quality of the output voltage by reducing the higher harmonics. AC – AC converters should be divided into two types: indirect AC – AC converters and direct AC – AC converter [3]-[4]. Conventional DC-link converter belongs to indirect AC-AC converter whereas matrix converter (MC) is a family member of direct converter. MC required bi-directional switches (BDS) but there is no need for conventional converter.

Harmonic losses not only reduces efficiency but also increase motor rating, which produces thermal over loading of IM even at light load condition [5]-[6]. The unique feature of MC is to produce pure sinusoidal output current waveform with minimum harmonic distortion by employing proper switching strategy [9].The performance has been analyzed on the basis of torque pulsation and motor rating.

II. CONVENTIONAL DC-LINK CONVERTER FED INDUCTION MOTOR DRIVE

Rectifier circuit consists of three legs six switches uncontrolled diode bridge. Inverter circuit consists of three legs fully controlled (IGBT/MOSFET) switches.

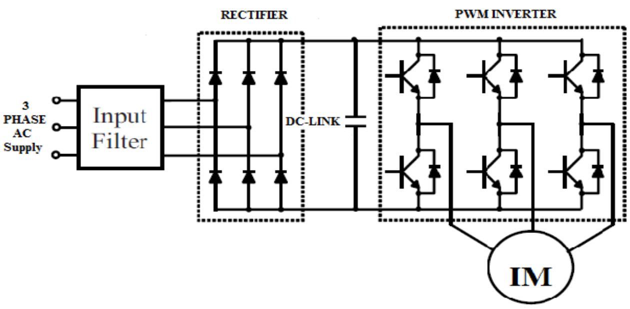

Fig. 1 Conventional DC-link converter fed induction motor

Conventional converter has some constructional draw back are follows:

- size/volume ratio high due to presence capacitor
- restricted to be used in high temperature application
- output supply contained dc harmonic component

Conventional DC-link converter has some practical advantages such as

- simple in construction
- no need of BDS

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A. Working operation of dc-link converter

In first stage, input AC supply is converted into constant DC voltage which is store in capacitor. The magnitude of DC voltage is depending upon peak value of input voltage (1).

$$V_{dc} = \frac{3V_m}{\pi} \quad (1)$$

In second stage, DC voltage is converted back to AC voltage of variable magnitude and frequency. In this stage switching pulses are provided in such a manner that to obtain desired value of output voltage. The magnitude of rms AC voltage by using pulse width modulation technique is depending on modulation gain ratio (2).

$$V_{ac} = \frac{m V_{dc}}{2\sqrt{2}} \quad (2)$$

where, *m* is modulation index

For safe operation of inverting mode, at least three switches must be ON and other should be OFF.

3. No two switches of same leg should not be ON
4. No three switches of same phase should not be ON

III. MATRIX CONVERTER FED INDUCTION MOTOR DRIVE

MC is advanced circuit topology capable of direct power converter which converter power in single stage.

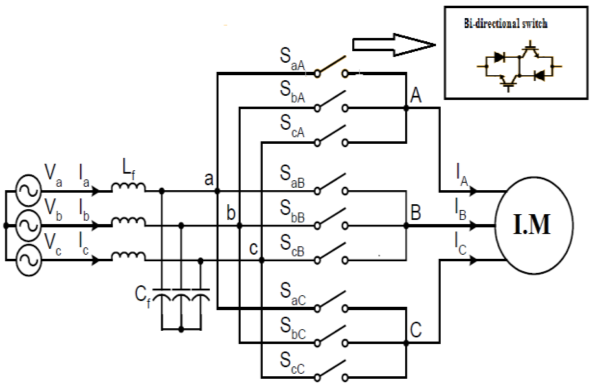

Fig. 2 Induction motor with matrix converter

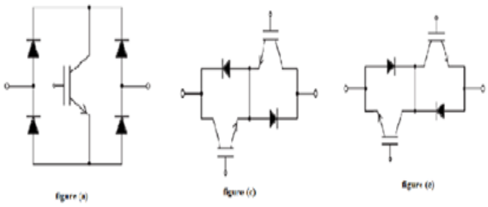

Fig. 3 shows possible configuration of bi-directional switches (a) Diode Embedded Bi-directional, (b) Common Emitter Bi-directional switch, (c) Common Collector Bi-directional switch

A. Working operation of matrix converter

Three phase output voltage in terms of switching function (3) are explaining basic working operation of matrix converter [11].

$$[v_o] = [m_{ij}][v_{in}] \quad (3)$$

Here, v_o , v_{in} are output, input voltage respectively
m_{ij} is modulation index matrix of switch S_{ij}

$$[v_o] = v_{om}\begin{bmatrix}\cos(\omega_o t)\\ \cos(\omega_o t-120^\circ)\\ \cos(\omega_o t+120^\circ)\end{bmatrix} \quad [v_{in}] = v_{im}\begin{bmatrix}\cos(\omega_i t)\\ \cos(\omega_i t-120^\circ)\\ \cos(\omega_i t+120^\circ)\end{bmatrix} \quad (4)$$

where, v_{om} and v_{in} are peak value of input and output voltages respectively. ω_o and ω_i are input and output frequency respectively.

$$[m_{ij}] = \begin{bmatrix} m_{aA} & m_{aB} & m_{aC}\\ m_{bA} & m_{bB} & m_{bC}\\ m_{cA} & m_{cB} & m_{cC}\end{bmatrix}\begin{bmatrix} S_{aA} & S_{aB} & S_{aC}\\ S_{bA} & S_{bB} & S_{bC}\\ S_{cA} & S_{cB} & S_{cC}\end{bmatrix} \quad (5)$$

where, $i=a,b,c$ are input coefficient &
$j=A,B,C$ output coefficient

$$m_{ij} = \frac{t_{ij}}{T_{seq}} \quad (6)$$

where, t_{ij} is switch ON time for switch S_{ij}

$$T_{seq} = \frac{1}{f_s} \quad (7)$$

$$S_{ij} = \begin{cases} 1 & \text{opened} \\ 0 & \text{closed} \end{cases} \quad (8)$$

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IV. SWITCHING STRATEGY FOR CONVENTIONAL CONVERTER

One of the advantages of conventional DC-link converter is simple switching strategy. To obtain desired value of output voltage of variable frequency and magnitude, the proper switches must be ON at particular instant. The various modulation schemes investigated for inverting mode operation presented [1] - [2] are:

- Pulse Width Modulation (PWM)
- Sinusoidal Pulse Width Modulation(SPWM)
- Space Vector Pulse Width Modulation(SVPWM) strategy

Among all these switching strategy SPWM is simple than other one. In this modulation scheme sinusoidal waveform (reference signal) compare with triangular wave (carrier) to generate switching pulses. Frequency of triangular waveform decides output frequency of output voltage and peak amplitude of reference waveform decides magnitude of output voltage.

TABLE –I SWITCHING TABLE FOR INVERTER MODE OPERATION

Sr. No	S1	S2	S3	S4	S5	S6	V_{AB}	V_{BC}	V_{AC}
1	ON	ON	OFF	OFF	OFF	ON	V_S	0	$-V_S$
2	ON	ON	ON	OFF	OFF	OFF	0	V_S	$-V_S$
3	OFF	ON	ON	ON	OFF	OFF	$-V_S$	V_S	0
4	OFF	OFF	ON	ON	ON	OFF	$-V_S$	0	V_S
5	OFF	OFF	OFF	ON	ON	ON	0	$-V_S$	V_S
6	ON	OFF	OFF	OFF	ON	ON	V_S	$-V_S$	0
7	ON	OFF	ON	OFF	ON	OFF	0	0	0
8	OFF	ON	OFF	ON	OFF	ON	0	0	0

V. SWITCHING STRATEGY FOR MATRIX CONVERTER

One of the limitations of MC is complicated switching strategy which restricted to be used as modern converter for industrial application. Three phase output voltage with variable magnitude and unrestricted frequency is obtained by turning ON/OFF appropriated bidirectional switch.

[illegible]

where, $\omega_i=2*\pi*f_i$ and $\beta_k=0,2\pi/3,4\pi/3$

[illegible]

VI. MATLAB SIMULATION OF DC-LINK CONVERTER DRIVING INDUCTION MOTOR

Power circuit of converters has been modelled using power electronic toolbox in Matlab/Simulink.

Bridge block provide operation of converting three phase AC supply into DC which is stored in energy storage capacitor. While performing inverting mode operation the gating pulses provide by discrete pulse width generator block.

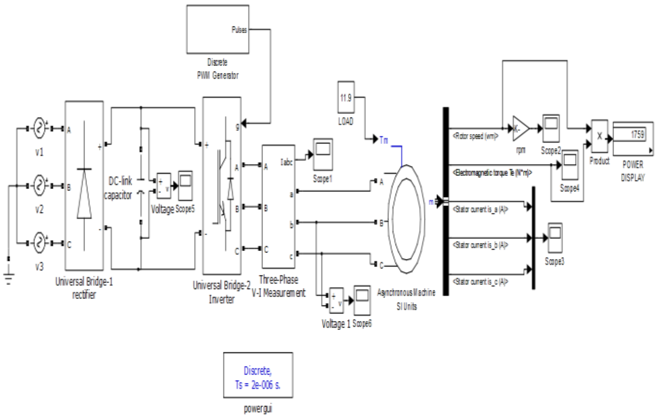

Fig. 4 MATLAB Simulink model of DC- link converter driving Induction motor

A. Results analysis: DC-Link converter fed IM drive

Simulation results were given in Fig. 5(a)-5(f). Fig.5 (a) shows three phases line to line voltage. Fig.5 (b) shows the stator currents of the IM for three phases. Fig.5(c) shows speed variation IM, Fig. 5(d) shows the electromagnetic torque variations of IM, Fig. 5 (e) shows pulsation which in between (13.1-10.49) N-m, Fig.5 (f) shows the THD analysis of output side current harmonics distortion and it is found to be around 8.04%.

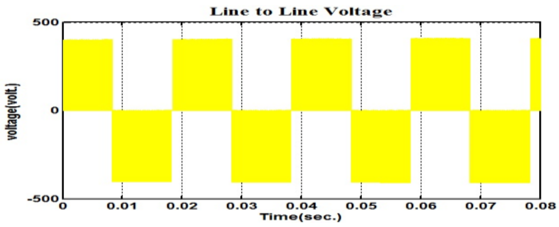

Fig. 5(a) Line to Line voltages (volt.)

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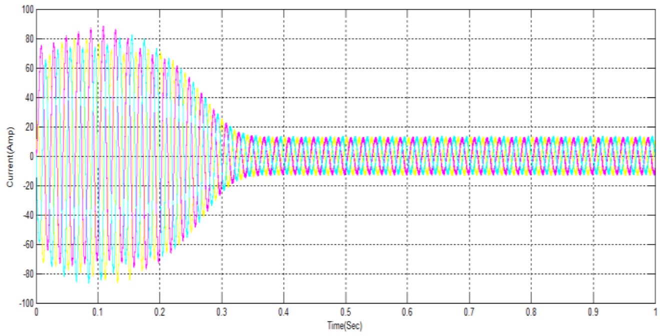

Figure5. (b) stator currents (Amp.)

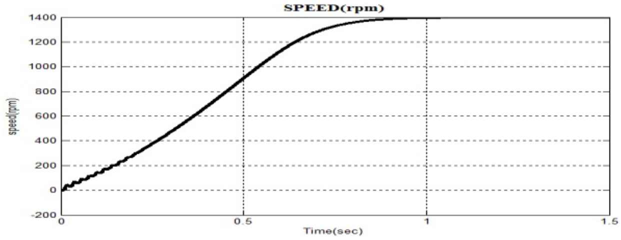

Figure 5(c) Speed (rpm)

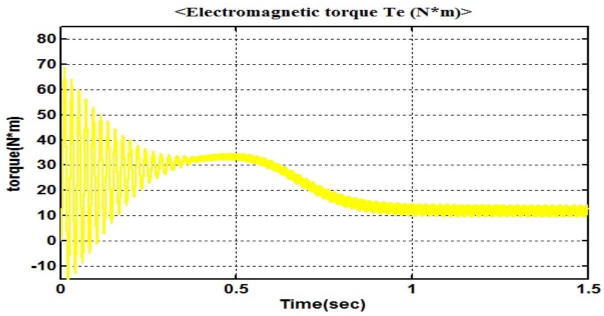

Figure 5(d) Torque (N-m)

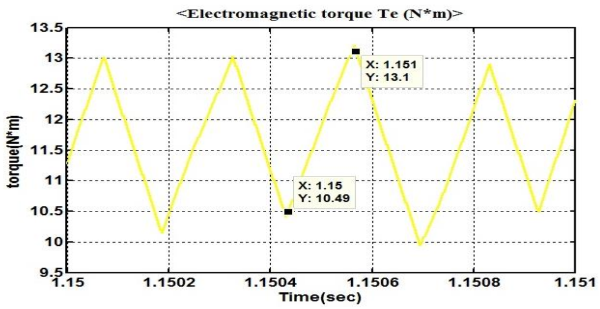

Figure 5(e) Torque pulsation

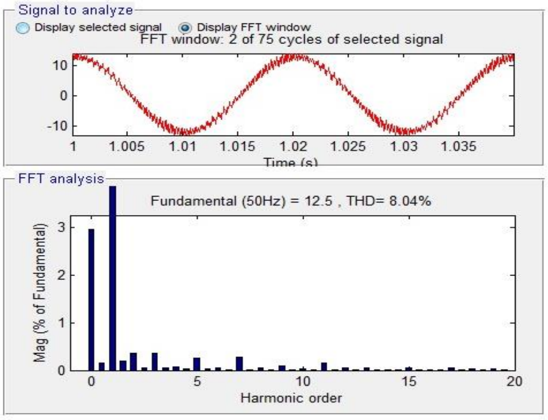

Fig. 5(f) THD Analysis

VII. MATLAB: DRIVING INDUCTION MOTOR

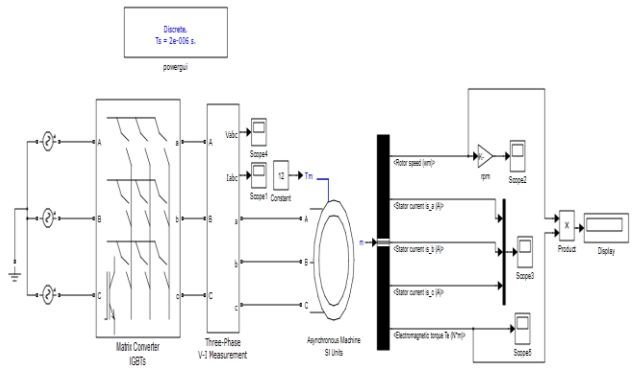

Fig.6. Matrix Converter for Induction Motor

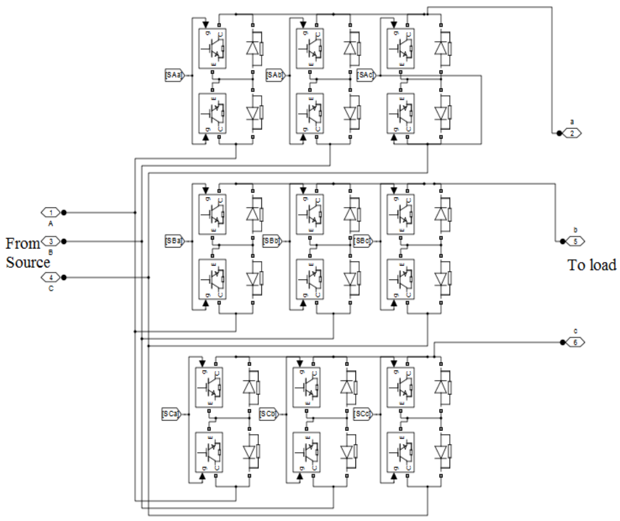

Fig.7 Three Phase Matrix Converter

The supply current harmonics of converter is reduced by filter so that converter is operated properly.

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A. Results analysis of matrix converter fed IM drive

Fig.7.1 shows three phases line to line voltage. Fig.7.3 represent speed variation IM, 7(e) represent torque pulsation is between (12.93-11.01)N-m, Fig.7.6 represent the THD analysis for output side current harmonics distortion and it is found to be around 4.54%.

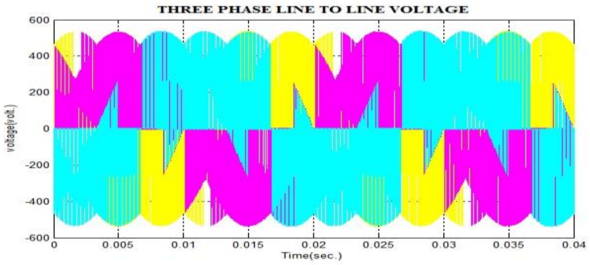

Fig. 7.1 L to L voltage

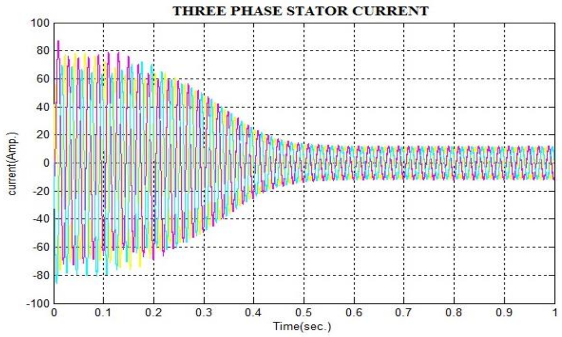

Fig. 7.2Stator currents (Amp.)

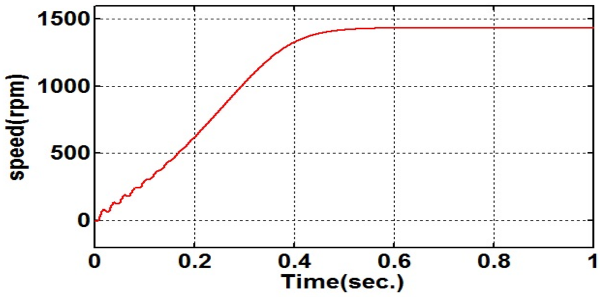

Fig. 7.3 Speed in rpm (rpm)

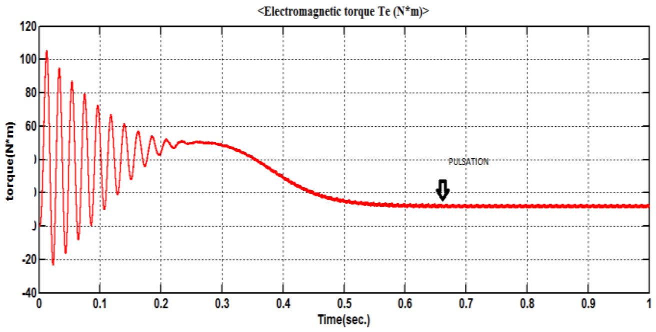

Fig. 7.4 Electromagnetic torque (N-m)

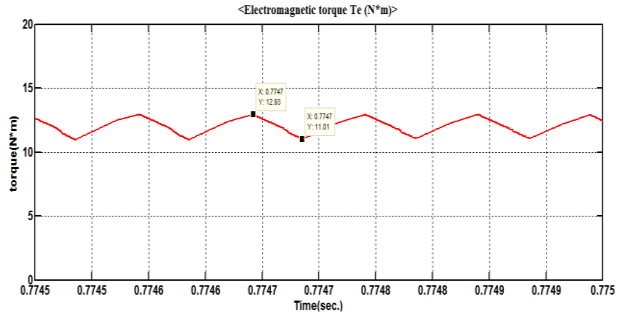

Fig. 7.5 Torque pulsation

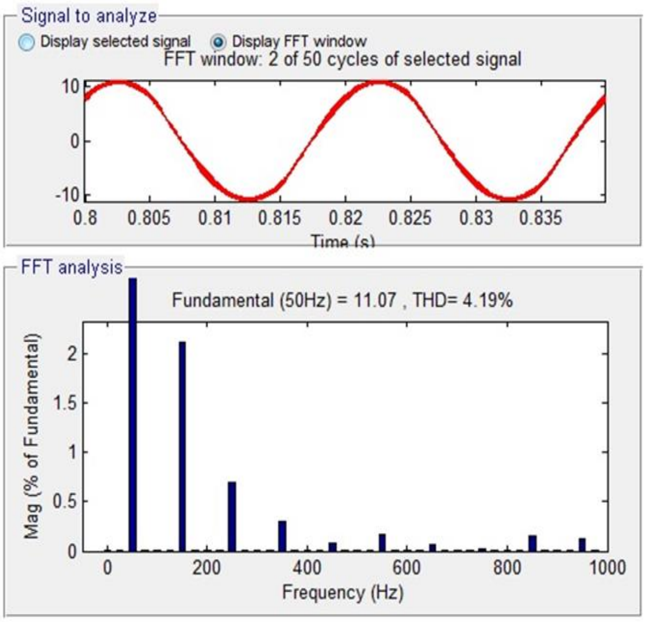

Fig. 7.6 THD Analysis

VIII. CONCLUSION

A paper shows a comparative performance of DC link converter and matrix converter for driving IM to reduce current harmonics distortion. It is noted that DC link converter draws THD reach up to 8.09% whereas matrix converter 4.14%. The torque pulsation of I.M. produced by matrix converter is lies between (12.93-11.01) N-m which is less than (13.01-10.49) N-m as produced by DC-link converter. A closed mathematical and theoretical description of matrix converter will provide future demands of compact energy saving drive system for industrial use.

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