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Performance Improvement of Asynchronous Motor using Matrix Converter

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Abstract— **A matrix converter is an array of controlled switches. These switches consist of various semiconductor devices. Switches are directly connected to a three-phase source and the output of the matrix converter is three-phase load. Matrix converter has various fascinating features that have been reviewed in the last three decades. Recent work is focused on designing an algorithm for different switching patterns. These algorithms are designed according to industrial applications. In this paper, we use one of the switching patterns to improve asynchronous motor performance. An important part of the paper is to improve the performance of the motor as compared to a simple asynchronous motor. The results of the study suggest that we get the improved performance of the asynchronous motor.**

I. INTRODUCTION

In any industry, the asynchronous motor is used for several purposes such as compressors, pumps, rollers, etc. The latest advanced semiconductor devices allowed and implement a new technique. Some speed control methods like field-oriented control, slip frequency control, indirect speed control, and vector control. Some modern control theory for asynchronous like optimal control, adaptive control, variable structure control, neural network, direct torque control, and others are published recently. Two main things for speed control of the synchronous motor are highly precise speed control and maintaining a constant speed. Matrix converter is one of the most significant innovations on account of relative simplicity and flexibility. The sketch for matrix converter circuit is as shown in Fig. 1. It contains a semiconductor switch that directly connects each input phase to each output phase to connect the output phase without intervening DC-link semiconductor switch operates at a specific time duration.

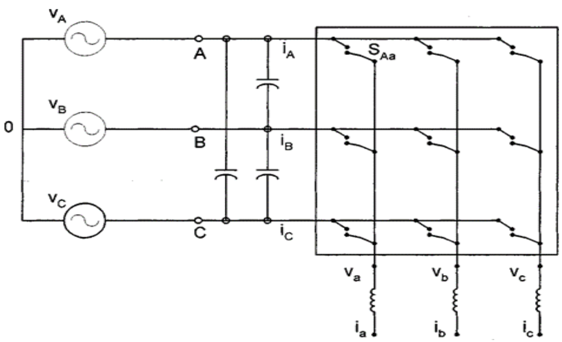

Fig. 1. Circuit diagram for matrix converter

A most important feature of matrix converter:-

1. Straightforward and compact circuit.
2. Generation of voltage and frequency at arbitrary values.
3. Input and output are sinusoidal.
4. Working with unity power factor and different load conditions.
5. Resurrection capability

II. LITERATURE VIEW

The power transistor is used to implement in bidirectional switches to make a matrix converter more significant. However, the development of a matrix converter starts with the Venturini and Alesina publish in 1980[1] [4]. They present a power circuit of the converter as a matrix of bidirectional power switches and they introduced the name “matrix converter”. Thereafter some researchers conducted mathematical analysis on low-frequency behavior of the converter. It gave a new term known as the “low-frequency modulation matrix”. The output voltage is obtained by multiplication of the low-frequency modulation matrix with the input voltage. Another different control technique is “fictitious DC link” which is introduced by Rodriguez in 1983. In this technique, switches are arranged according to a matrix. Each output line is switched between the most positive and most negative input line using a PWM technique. Thereafter, voltage source inverter introduced in Conventional methods. This concept is known as “indirect transfer function”.

In 1989, Burany[16] introduced the name “semi-soft current commutation” to allow the safe operation of the switches. Other commutation strategies were introduced by Ziegler et all. [5][9] and Clare and wheeler in 1998 [10][11][12]. The recent researches are focused on operation, techniques, operation under abnormal condition, input filter design, and ride-through capability. The main part of asynchronous motor is a speed control system and the interest of industry is focused on trouble-free operation during the running time

The purpose of this paper is to study the matrix converter and MATLAB implementation on the asynchronous motor. The performance of the asynchronous motor is compared with and without a matrix converter. To improve the performance of the asynchronous motor, we use a matrix converter. Matrix converter AC or DC input supply to required variable AC or DC output without any intermediate process, matrix converter provides AC and DC output concurrently by using a single control circuit.

III. METHODOLOGY

Matrix converter is a single-stage converter, which consists of bidirectional switches. The switches are directly connected to the input phase voltage.

Generally, three-phase voltage is used in industries. Hence, we used a matrix converter (3×3) and the output of the matrix converter acts as input for the asynchronous motor.

Matrix converter fed with voltage source so input terminals are not short circuit. Most of the application load is inductive (asynchronous motor is also inductive load) so the output phase never is opened. Switching operation

$$S_{Kj} = \begin{cases} 1, & \text{Switch } S_{Kj} \text{closed} \\ 0, & \text{Switch } S_{Kj} \text{open} \end{cases} \qquad K = \{A,B,C\} \qquad j = \{a, b, c,\}$$

$$S_{Aj} + S_{Bj} + S_{Cj} = 1 \qquad j = \{a, b, c\}$$

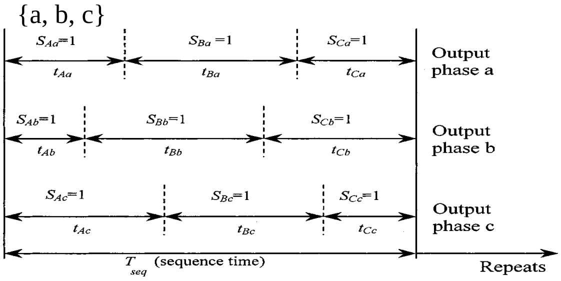

Fig. 2. General form of the switching pattern.

The load and supply voltages are referred to the source neutral, “0” in Fig. 2, and expressed as vectors form

$$V_o = \begin{bmatrix} V_a(t) \\ V_b(t) \\ V_c(t) \end{bmatrix} \qquad V_I = \begin{bmatrix} V_A(t) \\ V_B(t) \\ V_C(t) \end{bmatrix}$$

Load voltage and input voltages are expressed as

$$\begin{bmatrix} V_a(t) \\ V_b(t) \\ V_c(t) \end{bmatrix} = \begin{bmatrix} S_{Aa}(t) & S_{Ba}(t) & S_{Ca}(t) \\ S_{Ab}(t) & S_{Bb}(t) & S_{Cb}(t) \\ S_{Ac}(t) & S_{Bc}(t) & S_{Cc}(t) \end{bmatrix} \begin{bmatrix} V_A \\ V_B \\ V_C \end{bmatrix}$$

$$V_o = T.V_i \qquad (1)$$

where T= instantaneous transfer matrix.

The relationships between input and output currents is defined as

$$i_i = \begin{bmatrix} i_a(t) \\ i_b(t) \\ i_c(t) \end{bmatrix} \qquad i_o = \begin{bmatrix} i_A(t) \\ i_B(t) \\ i_C(t) \end{bmatrix}$$

$$i_i = T^T . i_o \qquad (2)$$

where T^T is transpose matrix of T.

By considering, bidirectional power switches work with the high switching frequency, a low-frequency output voltage of variable amplitude, and frequency generated by modulating a duty cycle of switches.

Let $m_{Kj}(t)$ is the duty cycle of S_{Kj}.

$$m_{Kj}(t) = {t_{Kj}}/{T_{seq.}} \qquad (3)$$

$$0 < m_{Kj} < 1 \qquad K = \{ A,B,C\} \qquad j = \{a,b,c\}$$

Low frequency transfer matrix

$$M(t) = \begin{bmatrix} m_{Aa} & m_{Ba} & m_{Ca} \\ m_{Ab} & m_{Bb} & m_{Cb} \\ m_{Ac} & m_{Bc} & m_{Cc} \end{bmatrix}$$

Low-frequency output phase voltage

$$V_o(t) = M(t).V_i(t) \qquad (4)$$

Low-frequency component input current is

$$i_{i=} M(t)^T . i_o \qquad (5)$$

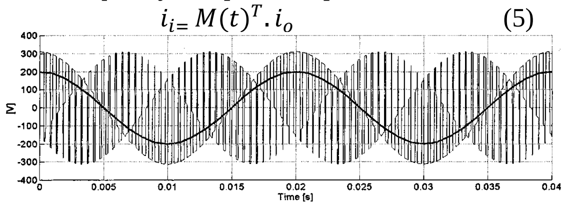
Fig. 3. Voltage with matrix converter.

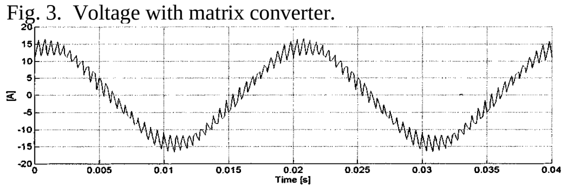
Fig.. 4. Load-Current waveform

IV. ASYNCHRONOUS MOTOR DRIVE

An asynchronous motor is used widely in the industries. In the last couple of years, it is used for fixed as well as variable speed applications. In the latest research, some control schemes like scalar control and vector control, are introduced, which led to rapidly changed the scenario of the asynchronous motor drive. Hence the demand for the asynchronous motor has also increased.

Cage type synchronous motor is commonly used. Many studies have been conducted on the different type of speed control method for induction motor . Two type of speed control method (a) One stator side, speed can control by varying the supply voltage or using power converter such as ac voltage controller, back to back converter, etc.(b) Other is rotor side control, speed is varying by rotor resistance or by injecting emf on the rotor side. In this paper, we use a stator voltage control method with the help of a matrix converter.

Normally voltage source is used in matrix converter so that the input side of this converter never is short-circuited. If input side short circuit than huge current flow through the switch and get damage due to over current. similarly at the output side of the matrix converter never kept open-circuited if the output side of the matrix converter is left open-circuited than overvoltage across the switch so it may cause damage the switch.

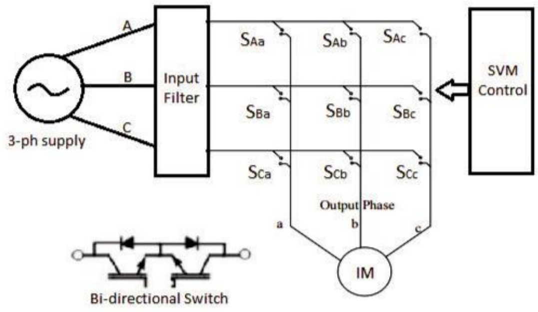

Fig . 5. Asynchronous motor fed with matrix converter.

V. BIDIRECTIONAL SWITCH

The matrix converter requires a bidirectional switch. These switches are capable of blocking voltage and conducting current in both directions.

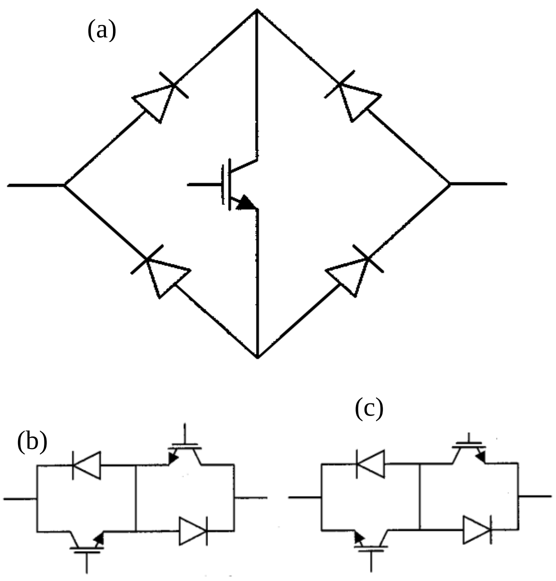

Fig.6. (a) Bidirectional switch using diode, (b) Common emitter type switch and (c) Common collector type switch.

VI. RESULT AND DISCUSSION

MATLAB\simulation model is developed to compare the result with and without matrix converter asynchronous motor. Motor runs at different torque value and the result is observation.

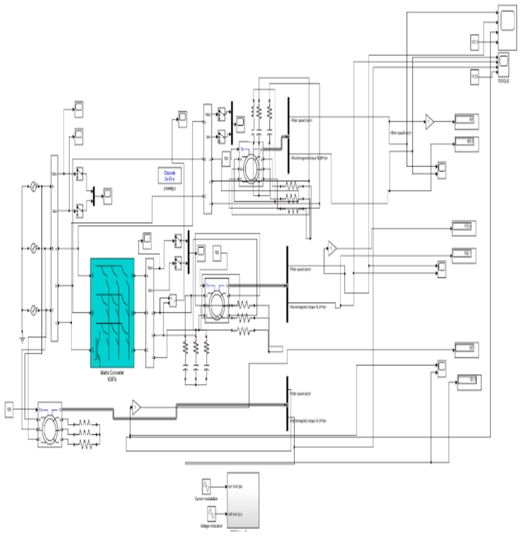

Fig 7. MATLAB model for the asynchronous motor with and without matrix -converter

(A) *WITHOUT MATRIX CONVERTER*

CASE 1- Response of asynchronous motor at T = 22 n-m. From Fig.8, starting rotor current 155A and finally steady-state value 11.50A in 0.271(Sec.). Starting stator current value155A and final steady-state value 12.98A in 0.271sec. and speed at steady-state is 1399 rpm in 0.80 sec..

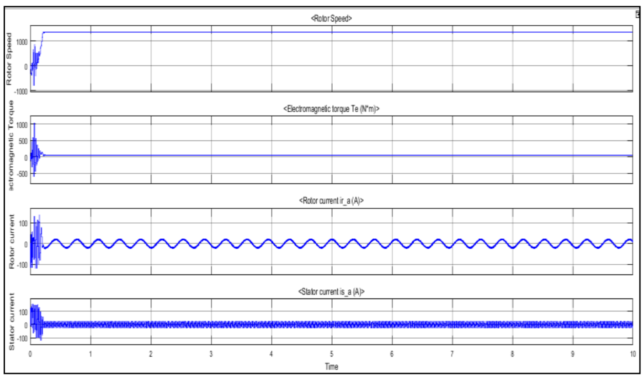

Fig. 8. Stator current, rotor current, electromagnetic torque, rotor speed at T= 22N-m.

CASE 2- Response of asynchronous motor at T = 36 n-m. From fig.9, starting rotor current 138A and finally steady-state value 16.20A in 0.210 (sec.). Starting stator current value157A and final steady-state value 18.10A in 0.210sec. and speed at steady-state is 1369 rpm in 31.99 sec.

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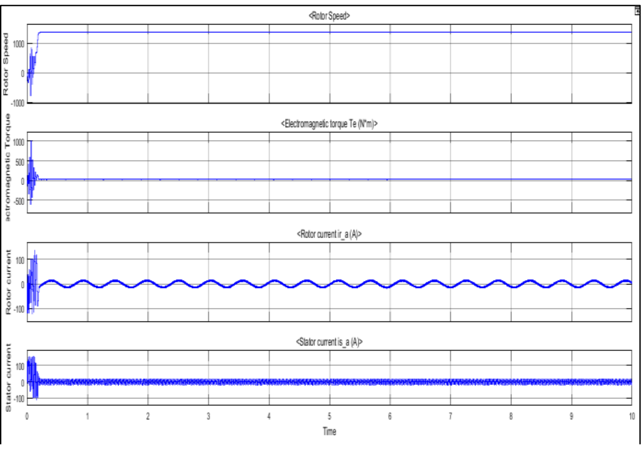
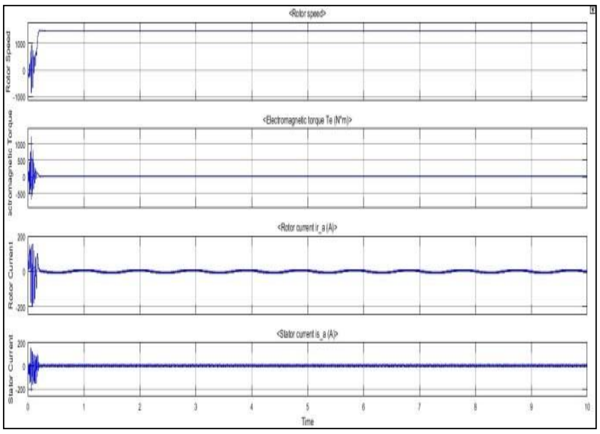


Fig. 9. Stator current, rotor current, electromagnetic torque, rotor speed at T= 36 N-m.

CASE 3- Response of asynchronous motor at T = 52 n-m. From fig10., starting rotor current 142A and finally steady-state value 24A in 0.220 (sec.). Starting stator current value161A and final steady-state value 25.11A in 0.220sec. and speed at steady-



state is 1356 rpm in 0.310 sec.

Fig. 10. Stator current, rotor current, electromagnetic torque, rotor speed at T= 52N-m.

(B) WITH MATRIX CONVERTER

CASE 1- Response of asynchronous motor at T = 22 n-m. From fig.11, starting rotor current 152A and finally steady-state value 8.614A in 0.249 (sec.). Starting stator current value154A and final steady-state value 10.20A in 0.249sec. and speed at steady-state is 1459 rpm in 0.297 sec.

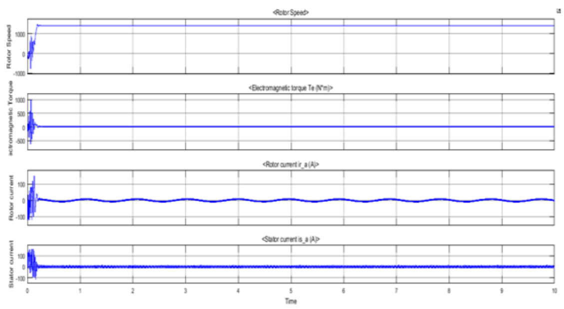
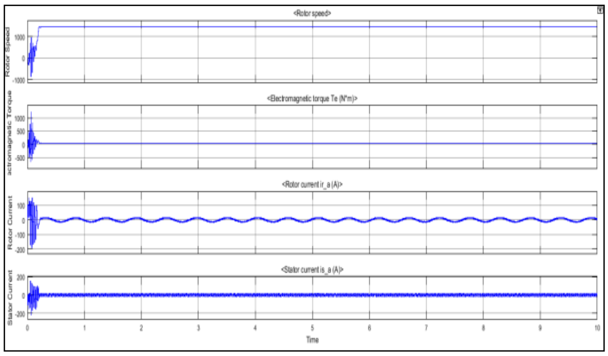


Fig. 11. Stator current, rotor current, electromagnetic torque, rotor speed at T= 22N-m

CASE 2- Response of asynchronous motor at T = 36 n-m. From Fig12., starting rotor current 152A and finally steady-state value 14.98A in 0.232 (sec.). Starting stator current value156A and final steady-state value 17.20.A in 0.232sec. and speed at steady-state is 1440 rpm in 0.306 sec.



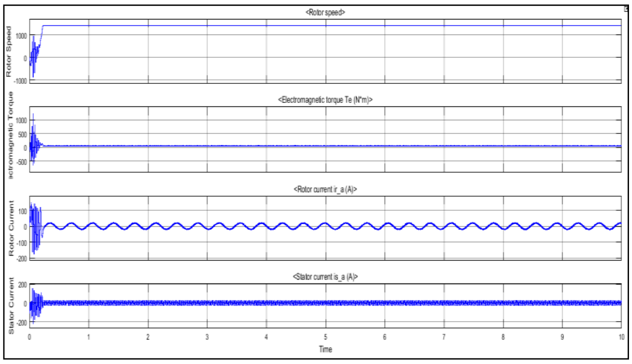


Fig. 12. Stator current, rotor current, electromagnetic torque, rotor speed at T= 36N-m.

CASE 3- Response of asynchronous motor at T = 52 n-m From Fig13., starting rotor current 152A and finally steady-state value 23.46A in 0.230 (sec.). Starting stator current value156A and final steady-state value 24.98A in 0.230sec. and speed at steady-state is 1410 rpm in 0.298 sec.

Fig. 13. Stator current, rotor current, electromagnetic torque, rotor speed at

T= 52N-m

RESULT IN TABLE I,,II,III

TABLE I
PERFORMANCE EVALUATION TABLE T = 22 N-M

Performance quantities	Without matrix converter		With matrix converter	
	Current(amp.)	Setting time(sec.)	Current(amp.)	Setting time(sec.)
Stator current	12.98	0.271	10.20	0.249
Rotor current	11.50	0.271	8.614	0.249
Motor speed	1399	0.80	1459	0.297

TABLE II
PERFORMANCE EVALUATION TABLE T = 36 N-M

Performance quantities	Without matrix converter		With matrix converter	
	Current(amp.)	Setting time(sec.)	Current(amp.)	Setting time(sec.)
Stator current	18.10	0.210	17.20	0.232
Rotor current	16.20	0.210	14.98	0.232
Motor speed	1369	0.319	1440	0.306

TABLE III
PERFORMANCE EVALUATION TABLE T = 52 N-M

Performance quantities	Without matrix converter		With matrix converter	
	Current(amp.)	Setting time(sec.)	Current(amp.)	Setting time(sec.)
Stator current	25.11	0.220	24.98	0.230
Rotor current	24.01	0.220	23.46	0.230
Motor speed	1356	0.310	1410	0.2978

VII. CONCLUSION

At starting, we observe that inrush current high in case of without matrix converter. High inrush current causes a dip in voltage so it is a danger for the motor. Inrush current is small in case of a matrix converter. A simulation model for three phases asynchronous motor with and without matrix converter. Matrix converter has bidirectional power flow capability. Steady-state value of speed at full load takes less time to compare with, without matrix converter. It means that matrix converter improves the system response and speed. The simulation result shows that better performance can be achieved by the use of a matrix converter.

APPENDIX

TABLE

MOTOR PARAMETER

Voltage	440V
Power	8 KW
Frequency	50 Hz
Pole pair	2
Torque	52 n-m
Speed	1450 rpm
Stator resistance	0.7451Ω
Rotor resistance	0.7526Ω
Stator inductance	0.003139H
Rotor inductance	0.003139H
Mutual inductance	0.1161H

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