# A Novel Frequency Changing Device: Matrix Converter

G. N. Surya
IV Semester, M. Tech. (EMS)
Rajiv Gandhi College of Engineering R. & T.,
Department of Electrical Engineering, Chandrapur,
Maharashtra, India - 442402

Subroto Dutt
Asst. Professor
Rajiv Gandhi College of Engineering R. & T.,
Department of Electrical Engineering, Chandrapur,
Maharashtra, India - 442402

## ABSTRACT

The field of soft conversion from one form to another has always been an area of continuous development. However, the recent developments are endorsed to exploring efficient means of single stage AC-AC conversion. Eliminating the energy loss involved in two stage AC-AC conversion has been the focal point for researchers these days. Thus, the present study is devoted to presents the most wanted know-how about the salient design features of Matrix Converter (MC), which provides the straight forward technique for converting fixed frequency at the input to variable frequency at the output. In the present study the simplified design of the single stage AC-AC converter is implemented in MATLAB using bidirectional ideal switches. It is not intended in this study just to list out various works done so for related with application areas of such converter but to bring forth the straight forward control and simulation results of the designed model, which is much needed and constitutes the interest area for researchers. The present simple yet formidable study establishes the brevity of fundamental concept representing the simplified design and its potential application in straight forward control of VFD's and Wind Energy Conversion System. The study first exhibits the design of frequency changer and then the model is used to control the speed of induction motor for 100 HZ and 25 HZ output frequencies. Results for change in frequency and variations in speed according to change in frequency have been obtained by simulating the model through MATLAB/simulink software. The waveforms of changed frequencies and varied speed generated by simulink confirm the results anticipated at design stage.

## Keywords

Bi-directional switches; conversion topologies; matrix converter (MC); simplified algorithm; variable frequency drives (VFDs

## 1. INTRODUCTION

After the development of controlled rectifiers in the year 1930, the first serious attempt in this direction was laid in 1964 by Schonung and Stemmler [1] who proposed the triangular carried-based sinusoidal pulse width modulation (PWM) technique for three-phase inverter modulation. The space vector modulation (SVM) strategy was proposedby Pfaff, Weschta and Wick in 1982 [2]. They based the proposed SVM method on the development of new technology microprocessors. The SVM algorithm was improved by Van der Broeck, Skudelny and Stanke [3]. This method became a basic modulation technique for three-phase PWM inverters. Pulse width modulated three-phase inverters can operate under voltage (open loop) or current (closed loop) control. Current-controlled systems have better performance and faster response than the voltage controlled systems because the control of the current is done in the inner loop of the control system [4].

In this chain of developments, "Matrix Converters" were first mentioned in the early 1980's by Alesina and Venturini [5]. The conventional SVM algorithm [6]-[7] usually generates both even and odd order harmonic voltages. The AC-AC Matrix Converter is optimal in terms of minimum switch number and minimum filtering requirements. A three-phase AC-AC conversion requirement can also be met through a back to back cycloconverter, but it uses 36 thyristers thus making the system quite bulky as shown in fig. 1.1.Some studies have dealt with operation at unbalanced input voltages [8], gate-drive concepts [9], and the commutation procedure

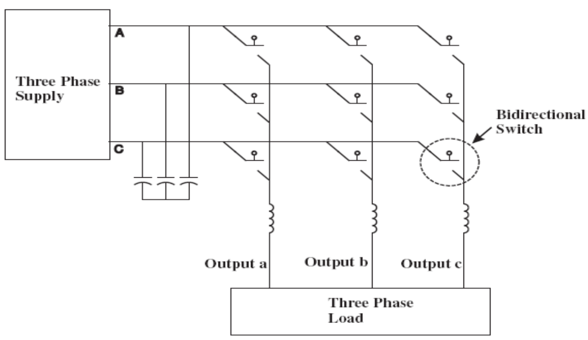


**Figure 1.1: Schematic of AC-AC converter: Source- MC for frequency changing power supply applications, S. Lopez, Ph.D. Dissertation.**

for bidirectional switches [10]. Problems in Commutations of matrix converter were dealt by L. Empringham [11]. A new modulation strategy was proposed for matrix converter by G. Clos [12]. A class of new AC-DC-AC MC referred as AC Chopper MC (ACCMC), was proposed in 2009, which generates high voltage transfer ratio which is not found in conventional AC-AC MC [13]. Effects of various abnormal voltage conditions on MC were studied and tests were carried

out to evaluate and improve the stability of the system under

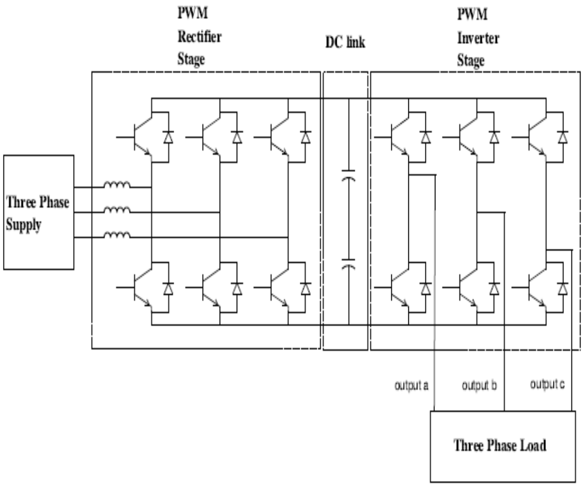


**Figure 1.2: Simplified representation of MC: Source-MC for frequency changing power supply applications, S. Lopez, Ph.D. Dissertation, Univ. of Nottingham, 2008.**

these conditions [14].

The characteristics desired in ac–ac single stage converter are: Eliminating the use of passive components such as large AC boost inductors and bulky and limited life time DC-link electrolytic capacitors. A three-phase AC-AC MC is shown in Figure 1.2.

## 1.1 STATEMENT OF THE PROBLEM

Minimizing the loss of energy involved in two stage conversion i.e. AC-DC-AC attracted the attention of many researchers. Hence, it is desired through this incorporated small study to apprise about the envisaged converter and propose the relative topology of AC-AC single stage conversion with the required output frequency.

## 2. METHODOLOGY

Testing of the model has been done for change in frequencies by connecting a resistive load and for variability of speed by connecting a squirrel cage induction motor as load; and simulation through MATLAB/simulink.

The concept of switching functions is used to derive a mathematical model of the matrix converter. Performance of MC with three different modulation techniques such as PWM, SVPWM and SVM was studied in April, 2010 [15] and it was observed that THD is better for SVM technique and that the performance of MC varies with the control technique used. H. Mohd. Hanafi, N.R. Hamzah, A. Saparon and M.K. Hamzah proposed an improved switching sequence of single phase Matrix Converter (SPMC) modulated by Sinusoidal Pulse Width Modulation (SPWM) [16]. H. Mohd. Hanafi, Z. Idris and M.K. Hamzah presented their work on modeling and simulation of SPMC as a frequency changer modulated by SPWM subjected to passive load conditions. IGBTs were used for switching device. [17].

To understand the modulation problem and its solution, consider the arrangement shown in Figure 1.2. Analysis of this arrangement shows that there are no freewheeling diodes. This restriction means that the short circuit in the capacitive input as well as the open circuit in the inductive output must be avoided. Because ideal switches are used, the commutation between switches is instantaneous. A typical switching pattern for matrix converter is shown in fig. 2.1.

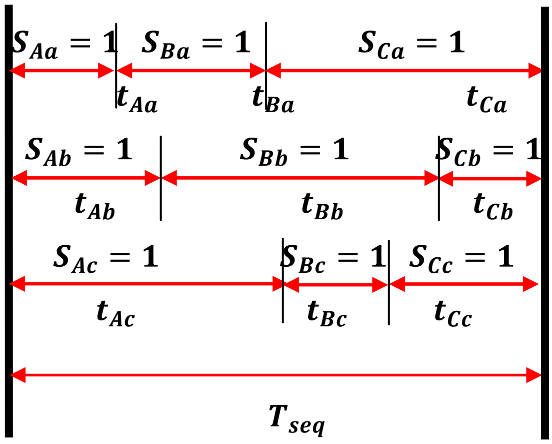


**Figure 2.1: Switch modulation scheme for proposed**

If conventional PWM is employed the switching sequence *Tseq* has a fixed period as shown in equation 1.

$$m_{Aa}(t) = \frac{t_{Aa}}{T_{seq}} \tag{1}$$

A modulation duty cycle should be defined for each switch in order to determine the average behavior of the matrix converter output voltage waveform. The modulation duty cycle is defined by equation 1, where *tAa* represents the time when switch *SAa* is ON and *Tseq* represents the time of the complete sequence in PWM pattern. For calculating the *tAa* and *mAa*, Venturni's simplified algorithm [18] is used in this study. The simplified algorithm is reproduced below: -

Vim and $\omega_{it}$ are calculated as

$$V_{im}^2 = \frac{4}{9}(v_{AB}^2 + v_{BC}^2 + v_{AB}v_{BC}) \tag{2}$$

$$\omega_i t = \arctan\left(\frac{v_{BC}}{\sqrt{3}\left(\frac{2}{3}v_{AB} + \frac{1}{3}v_{BC}\right)}\right) \tag{3}$$

Where, $V_{AB}$ and $V_{BC}$ are the instantaneous input line voltages. The target output peak voltage and the output position are calculated as

$$V_{om}^2 = \frac{2}{3}(v_a^2 + v_b^2 + v_c^2) \tag{4}$$

$$\omega_o t = \arctan\left(\frac{v_b - v_c}{\sqrt{3}\, v_a}\right) \tag{5}$$

where $V_a$, $V_b$, $V_c$ are the target phase output voltages. Alternatively, in a closed loop system (for example a fieldoriented controlled drive), the voltage magnitude and angle may be direct outputs of the control loop. Then, the voltage ratio is calculated

$$q = \sqrt{\frac{V_{om}^2}{V_{im}^2}} \tag{6}$$

Where, q is the desired voltage ratio, and Vim is the peak input voltage. Triple harmonic terms are found:

$$K_{31} = \frac{2}{9}\frac{q}{q_m}\sin(\omega_i t)\sin(3\omega_i t) \tag{7}$$

$$K_{32} = \frac{2}{9}\frac{q}{q_m}\sin\left(\omega_i t - \frac{2\pi}{3}\right)\sin(3\omega_i t) \tag{8}$$

$$K_{33} = \sqrt{V_{om}^2}\left[\frac{1}{6}\cos(3\omega_0 t) - \frac{1}{4}\frac{1}{q_m}\cos(3\omega_i t)\right] \tag{9}$$

Where, $q_m$ is the maximum voltage ratio (0.866). Then, the three modulation functions for output phase a are given as

$$M_{Aa} = \frac{1}{3} + k_{31} + \frac{2}{3V_{im}^2}(v_a + k_{33})\left(\frac{2}{3}v_{AB} + \frac{1}{3}v_{BC}\right) \tag{10}$$

$$M_{Ba} = \frac{1}{3} + k_{32} + \frac{2}{3V_{im}^2}(v_a + k_{33})\left(\frac{1}{3}v_{BC} - \frac{1}{3}v_{AB}\right) \tag{11}$$

$$M_{Ca} = 1 - (M_{Aa} + M_{Ba}) \tag{12}$$

## 3 FINAL DESIGN OF THE PROPOSED MODEL

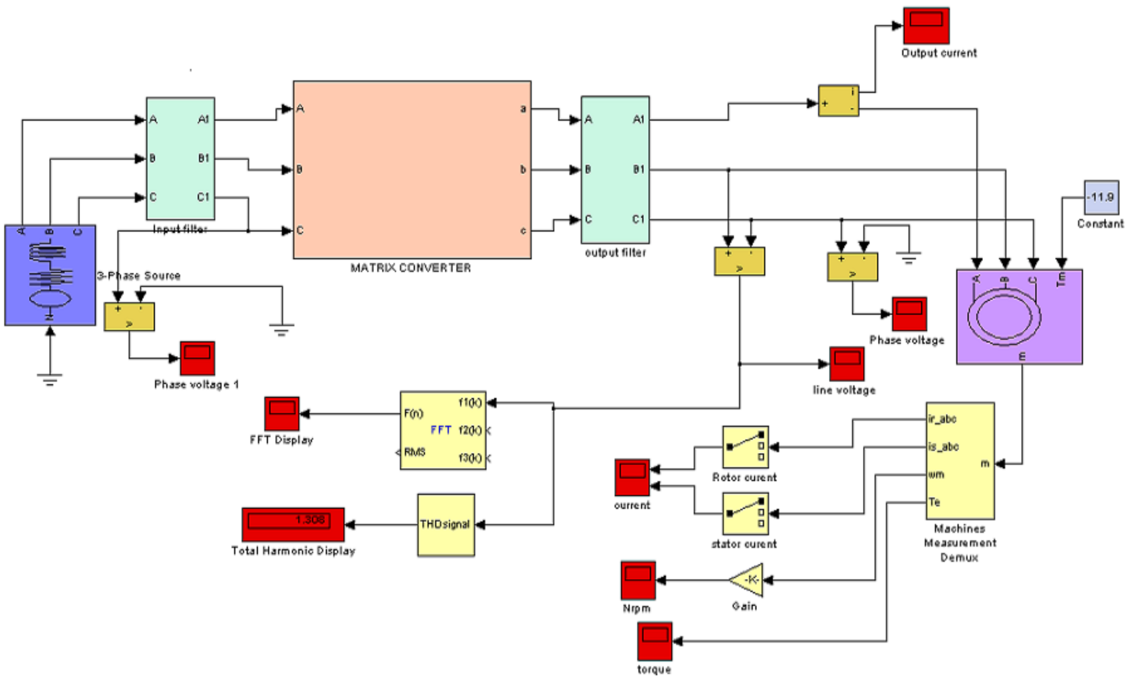


**Figure 3.1: Compact structure of Matrix Converter with motor as load**

## 4. RESULSTS

### Conversion of Input Frequency from 50 to 100 Hz

The result of controlling the speed of motor as well as the change in the frequency at the output have been obtained successfully and is evident through the waveforms generated by simulink and thus the envisaged model may be used for the purpose of enhancing the efficiency of the overall system as the conversion for required frequency is done in single stage.

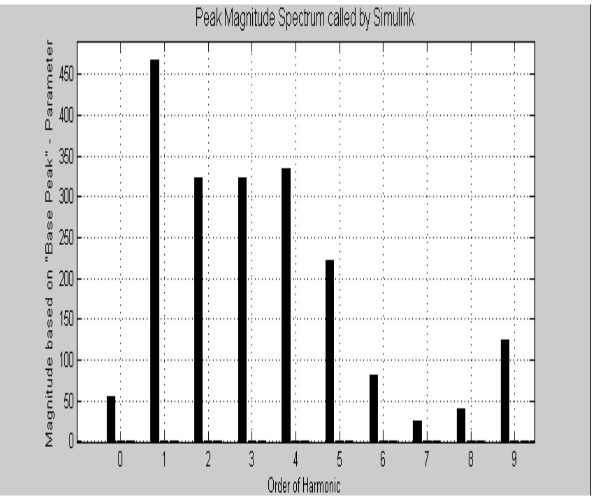


**Figure 4.1: Total harmonic distortion (100 Hz)**

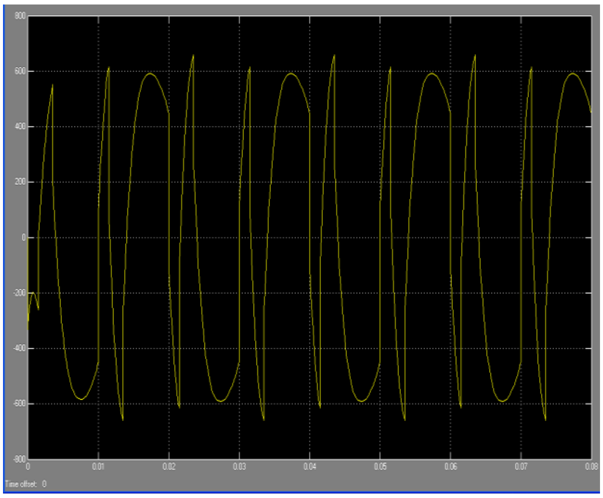

**Figure 4.2: Line Voltage with filter (100 Hz)**

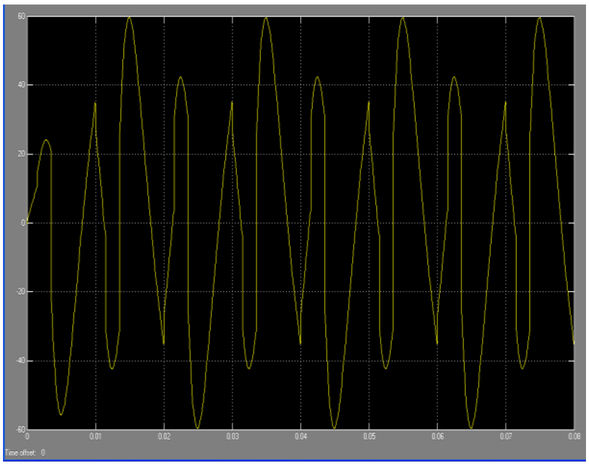

**Figure 4.3: Output Current with filter (100 Hz)**

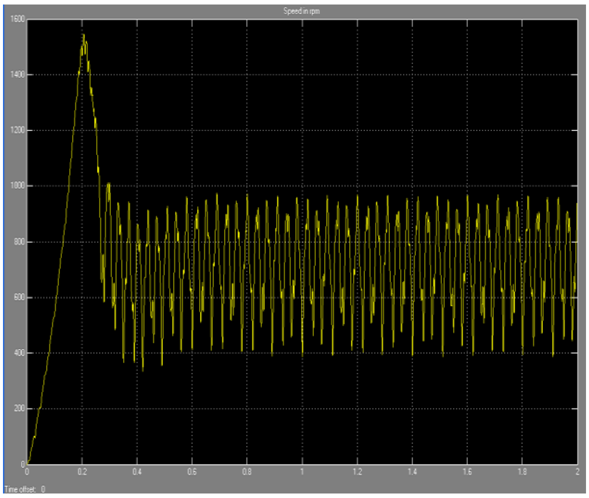

**Figure 4.4: Speed of motor obtained at 100 Hz**

## Conversion of Input Frequency from 50 to 25 Hz

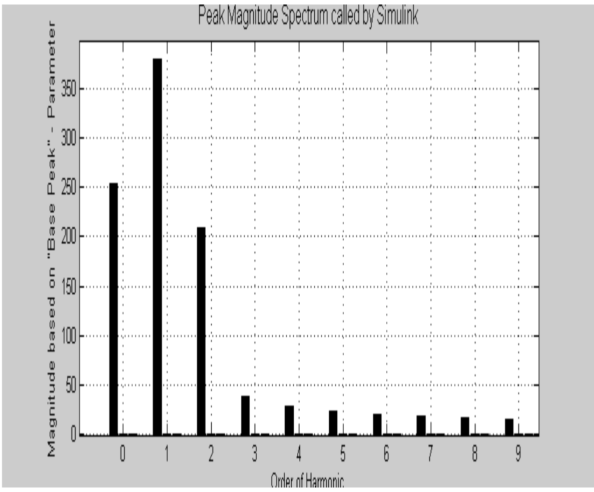


**Figure 4.5: Total harmonic distortion (25 Hz)**

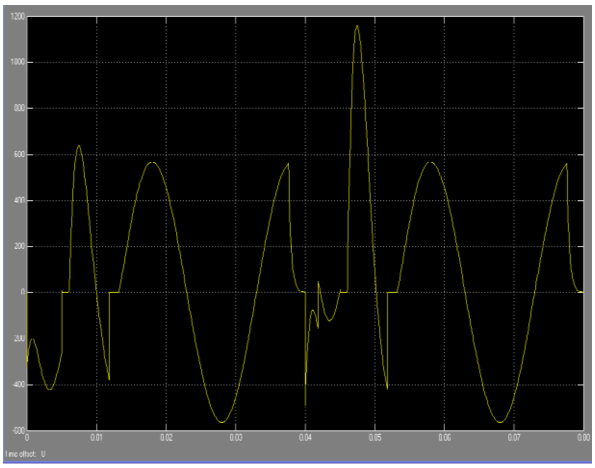

**Figure 4.6: Line Voltage with filter (25 Hz)**

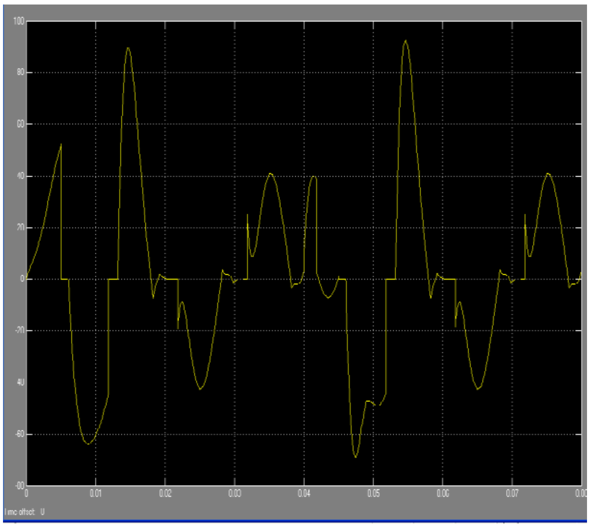

**Figure 4.7: Output Current with filter (25 Hz)**

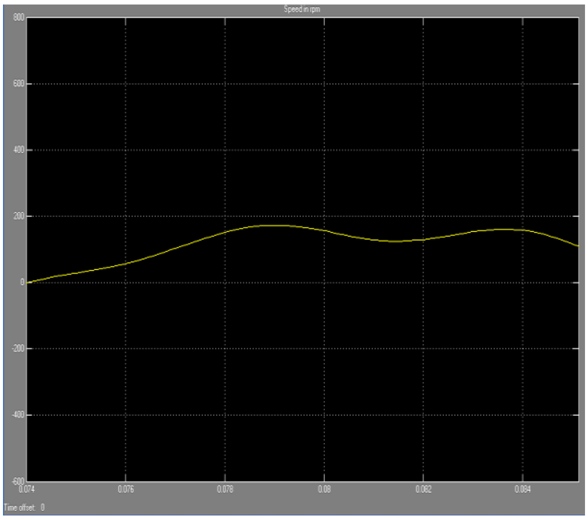

**Figure 4.8: Speed of motor obtained at 25 Hz**

## 5. CONCLUSIONS

Conversion topologies like matrix converter provides avenues for reduction of losses involved in conversion process. As the title of the study suggests, the aim of the present study was set to carry out the modeling of the single stage AC-AC conversion using the most exciting concept of Matrix Converter envisaged way back in 1980 and still holding the area of interest for the researchers. In the present study the converter modeling was implemented in MATLAB. The variable frequency output generated from the designed model for 100 Hz and 25 Hz was first used for generating the required output frequencies and then speed control of squirrel cage induction motor. The testing of the model for change in frequencies and speed control of induction motor was done through MATLAB/Simulink. The waveforms of the motor speed generated by simulation confirmed the variation of the speed with variation of frequency through simple yet very effective model of matrix converter giving out single stage three phase AC-AC conversion. The study thus is able to pinpoint the specific contribution of single stage converter in reducing the overall size of the converter by at least half (1/2) thus minimizing the space requirements and at the same time reduction in losses due to single stages of conversion.

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