Matrix Converter 3x5 with Calculated PWM Strategy for Feeding Induction Motor

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Abstract: ***In this paper, the control with calculated PWM strategy for the 3x5 matrix converter is presented and analyzes. The main aim of the presented matrix converter is to use in industrial application with five phases machine feeded by three phases network. This strategy is developed to control multi-phases matrix converter. A study is given for the control strategy is achieved according to the quality of the output voltage and current under five phases asynchronous machine as load based on the THD evaluation. Simulation results are presented for the validation of this control strategy and to clarify the main advantages.***

Keywords: Five phase induction motor, matrix converter 3x5, THD, calculated PWM strategy, direct AC-AC converter and three phases network**.**

1. Introduction

Variable speed electric drives predominately utilize the three-phase machine, however, since the variable speed AC drives require a power electronic converter for their supply, the number of machine phases is essentially unlimited. This has led to an increase in the interest in multiphase AC drive applications, since multiphase machines offer some inherent advantages over their three-phase [1], such as reducing the amplitude and increasing the frequency of torque pulsation, reducing the rotor harmonic current per phase without increasing the voltage per phase, lowering the dc-link current harmonics and higher reliability, high fault tolerance [2].

A matrix converter is variable amplitude and frequency power supply which converts the tree phase line voltage directly [5] – 6], without intermediate voltage or current link into the five phase output voltage.

However, the matrix converter has several advantages compared to the conventional inverters. It is obvious that this is an AC-AC converter without DC link connected to the input. On the other side the passive elements of the energy storage which form the intermediate circuit (generally capacitors) between the AC-DC conversion stage and the inverter are eliminated [3] – [4]. It is therefore possible to reduce considerably the volume and the cost of the conversion stage. Moreover the symmetry structure of the matrix converter allows ensuring the energy recovery directly to the supply system [5] – [6]. The main objective of the study of this converter is the replacement of conventional inverters with DC link intermediary circuit by a direct AC-AC converter and use multi-phases induction machine without special feed (simply fed the three phases), where new control algorithm are developed to ensure this conversion function.

2. Modeling of the Matrix Converter

2. 1 Structure of the Matrix Converter

The matrix converter is a static frequency and voltage converter; this is the main characteristic of conventional converters rectifier- inverter. It allows obtaining in output voltages a multiphase variable system: amplitude and frequency from an input multiphase's voltages of power supply network. [7] – [8]. This converter topology is characterized by a matrix of fifteen switches (matrix [3x5]); three phases of the network as input are connected to five output phases through bidirectional power switches. The switch matrix converter can be modeled by two diodes, and two transistors greatly to reduce the number of possible configurations of the matrix converter. [7] – [8]

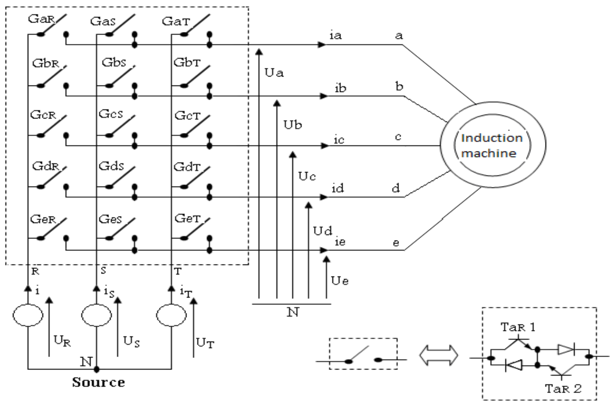

Figure 1: Schematic diagram of the matrix converter.

Since the converter is an idealized coupling, the principle of causality leads to precise rules concerning the grouping of switches forming the converter: [1] – [9]

- Sources located on both sides of the group are necessarily different in nature.
- Continuity requires energy to retain, among the possible configurations of the operative part, that those who are physically possible: a non-zero voltage source can be

short-circuited, a voltage source to zero can be set open circuit.

Finally we deduce that for each cell one and only one switch should be closed, is reducing the number of possible configurations to 3^5.

2.2. Cell work of a matrix converter

The cellular commutations present a symmetrical functional, and consequently a symmetrical control. The converter study is then reduced to the cellular commutation one. [10] [11]

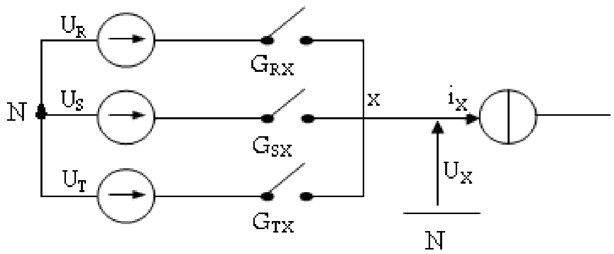

Figure 2: The cellular commutation of matrix converter.

The commutation cellular has 3 possible configurations. Each of these configurations is characterized quantity like it shown in table. 1.

Table 1: Possible Matrix Converter configuration

Configuration	*The electrical quantity which characterizes*
E_1	$U_A = U_R$
E_2	$U_A = U_S$
E_3	$U_A = U_T$

3. The calculated PWM modulation strategy

3. 1 Function of generating connection

The output functions of the converter must follow the reference voltages previously imposed [10] – [11].

- Let U_R, U_S *and* U_T input voltages of the matrix converter

$$\begin{cases} U_R = U_m \sin(\omega_i t) \\ U_S = U_m \sin(\omega_i t - 2\pi/3) \\ U_T = U_m \sin(\omega_i t - 4\pi/3) \end{cases} \quad (1)$$

- Let U_A, U_B, U_C, U_D *and* U_E the output reference voltages of the matrix converter

$$\begin{cases} U_A = rU_m \sin(\omega_o t) \\ U_B = rU_m \sin(\omega_o t - 2\pi/5) \\ U_C = rU_m \sin(\omega_o t - 4\pi/5) \\ U_D = rU_m \sin(\omega_o t - 6\pi/5) \\ U_E = rU_m \sin(\omega_o t - 8\pi/5) \end{cases} \quad (2)$$

With: $\omega_o = 2\pi f_o$: Pulse reference of output voltage phases

r : Rate of modulation.

The expressions of the converter voltage converter can be expressed as follows:

$$\begin{bmatrix} U_A \\ U_B \\ U_C \\ U_D \\ U_E \end{bmatrix} = \begin{bmatrix} F_{RA}^g & F_{SA}^g & F_{TA}^g \\ F_{RB}^g & F_{SB}^g & F_{TB}^g \\ F_{RC}^g & F_{SC}^g & F_{TC}^g \\ F_{RD}^g & F_{SD}^g & F_{TD}^g \\ F_{RE}^g & F_{SE}^g & F_{TE}^g \end{bmatrix} \begin{bmatrix} U_R \\ U_S \\ U_T \end{bmatrix} \quad (3)$$

With:

$$\begin{cases} F_{RA}^g + F_{SA}^g + F_{TA}^g = 1 \\ F_{RB}^g + F_{SB}^g + F_{TB}^g = 1 \\ F_{RC}^g + F_{SC}^g + F_{TC}^g = 1 \\ F_{RD}^g + F_{SD}^g + F_{TD}^g = 1 \\ F_{RE}^g + F_{SE}^g + F_{TE}^g = 1 \end{cases}$$

(4)

We can write equation (3) and (4) as follow:

$$\begin{cases} U_A - U_T = F_{RA}^g (U_R - U_T) - F_{SA}^g (U_S - U_T) \\ U_B - U_T = F_{RB}^g (U_R - U_T) - F_{SB}^g (U_S - U_T) \\ U_C - U_T = F_{RC}^g (U_R - U_T) - F_{SC}^g (U_S - U_T) \\ U_D - U_T = F_{RD}^g (U_R - U_T) - F_{SD}^g (U_S - U_T) \\ U_E - U_T = F_{RE}^g (U_R - U_T) - F_{SE}^g (U_S - U_T) \end{cases} \quad (5)$$

Three cases present:

$$\begin{cases} F_R^g = F_S^g = 0 \Rightarrow F_T^g = 1 \\ F_R^g = F_T^g = 0 \Rightarrow F_S^g = 1 \\ F_S^g = F_T^g = 0 \Rightarrow F_R^g = 1 \end{cases} \quad (6)$$

$$\text{With} \begin{cases} F_R^g = (F_{RA}^g, F_{RB}^g, F_{RC}^g, F_{RD}^g, F_{RE}^g) \\ F_S^g = (F_{SA}^g, F_{SB}^g, F_{SC}^g, F_{SD}^g, F_{SE}^g) \\ F_T^g = (F_{TA}^g, F_{TB}^g, F_{TC}^g, F_{TD}^g, F_{TE}^g) \end{cases}$$

3.2 Principle of the calculated modulation strategy

To determine the functions of discontinuous connection of matrix converter F which attack the switches, we must compare the generating functions for carriers. The various expressions of the conversion matrix are given in the table. 2.

$$\begin{cases} V^+ = Max(U_R, U_S, U_T) \\ V^- = Min(U_R, U_S, U_T) \end{cases}$$

Intervals	$V^- \le U \le V^+$	F_R^g	F_S^g	F_T^g
[0, π/6] ∪ [5π/6,7π/6 ∪ [11π/6, 2π]	U_R	0	$\frac{U_i - U_T}{U_S - U_T}$	$\frac{U_i - U_S}{U_T - U_S}$
[π/2, 5π/6] ∪ [3π/6,11π/6]	U_S	$\frac{U_i - U_T}{U_R - U_T}$	0	$\frac{U_i - U_R}{U_T - U_R}$
[π/6, π/2] ∪ [7π/6,3π/2]	U_T	$\frac{U_i - U_S}{U_R - U_S}$	$\frac{U_i - U_R}{U_S - U_R}$	0

As: $i = A,\ B,\ C,\ D\ and\ E$ respectively

4. Simulation Results

To have an overview about the behaviors of the presented algorithm, who is tested with simulation experiment with five induction motor as load, the input three-phase voltage of the matrix converter is a typical three-phase system which is characterized by a magnitude of $220V$ and a frequency of $50Hz$, the switching frequency is chosen to be $1550Hz$ with a modulation index $r = 0.8$. The five output voltage obtained by the application of the calculated PWM strategy is presented in Figure. 3, on the other side their harmonic spectrum is represented in Figure. 4. Whereas in Figure.5 the performance of the association matrix converter- five phases induction motor with Calculated PWM strategy, Application of rated load between t = 1.5 and 2 s are shown. In Table.3, the Fundamental voltage and THD voltage are presented. It is obvious that the calculated PWM algorithm give the maximum magnitude compared to the typical three-phase system without matrix converter equal 311.11 V.

Table 3: Fundamental and THD of voltage

Method	*calculated PWM strategy*
Fundamental Voltage	293.1 V
THD Voltage	77.23 %

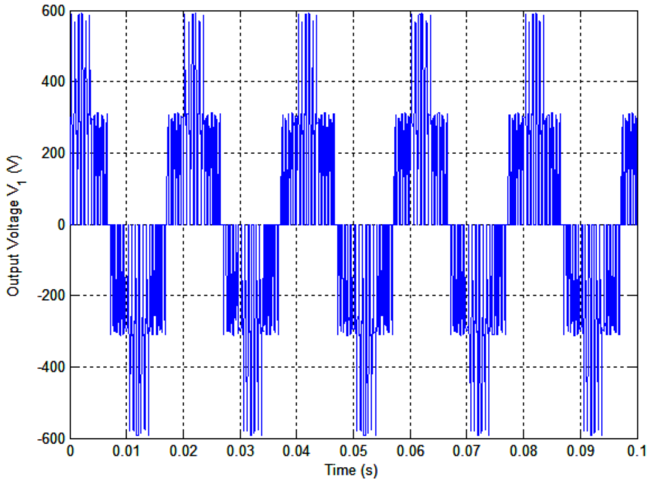

Figure 3: The output voltage obtained with calculated PWM strategy.

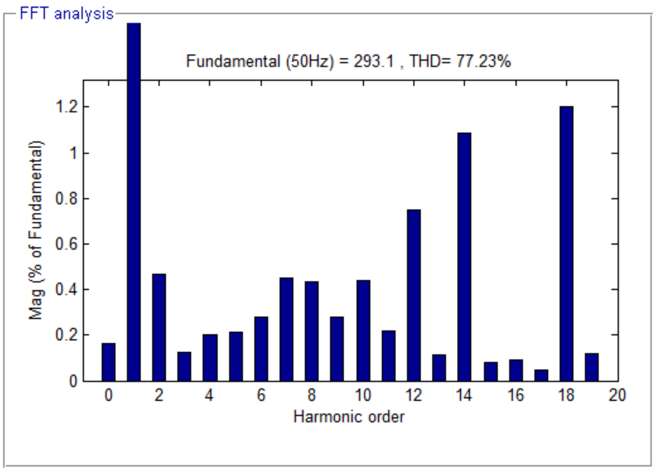

Figure 4: The harmonic spectrum of the output voltage obtained with calculated PWM strategy

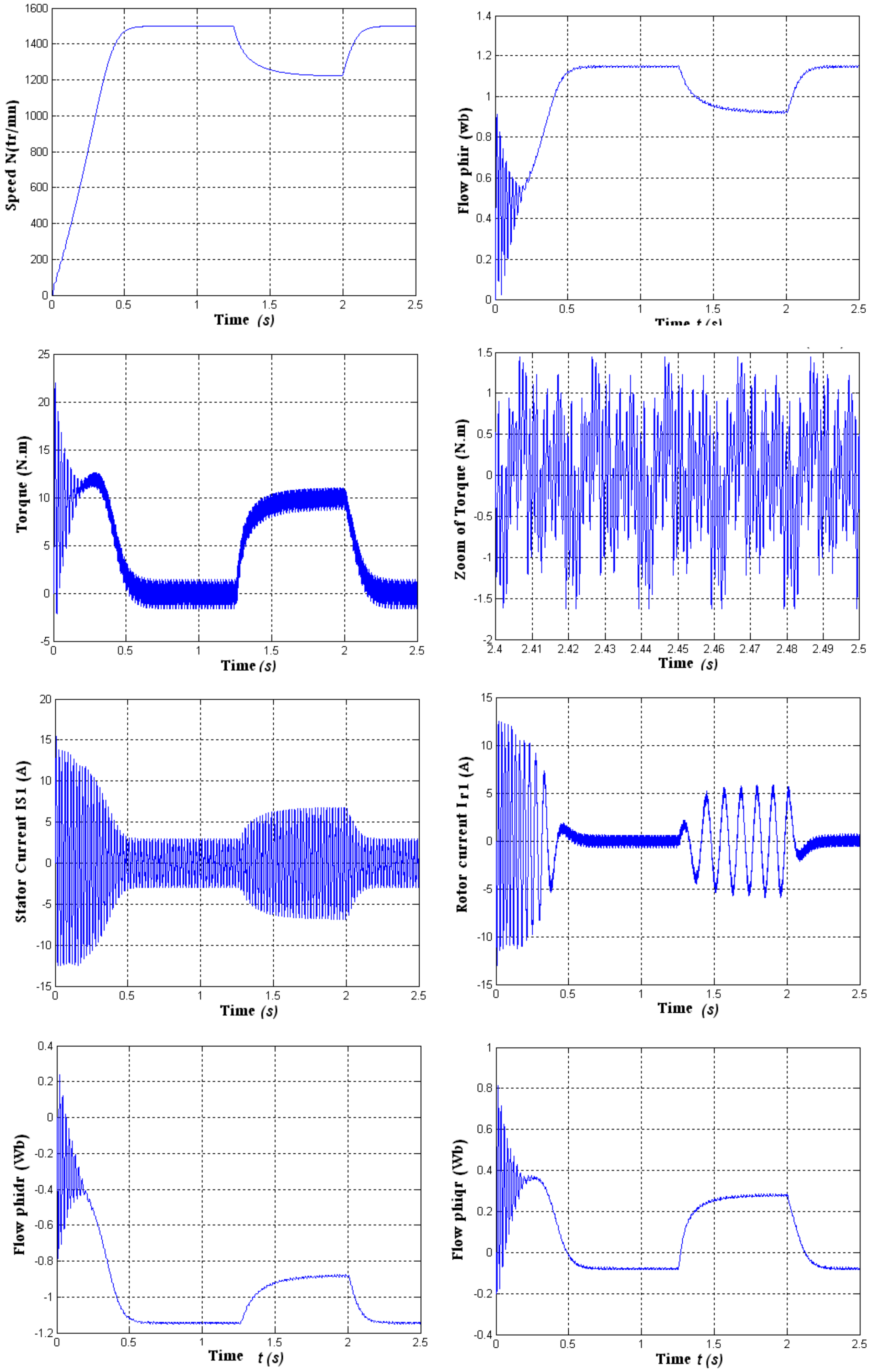

Figure 5: Performance of the association matrix converter- five phases induction motor with Calculated PWM strategy, Application of rated load between t = 1.5 and 2 s

5. Conclusion

This paper presents an approach for controlling 3x5 matrix converter feeding 5-phase AC. The developed technique can be used for any number of phases of an AC machine we just need to change some parameter of the main program. Simulation results of a five-phase induction machine controlled by 3x5 matrix converter are presented for the verification of the findings, the results obtained are satisfactory. Experimental investigations are ongoing and are the subject of a future paper.

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