Study of output voltages of a matrix converter feeding an five AC - induction Machine Using the strategy calculated modulation PMW

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Abstract:

In this article we present an analytical study with the use of the strategy calculated modulation to control a matrix converter.

From the start we made a model of matrix converter, then to obtain the amplitude and frequency of the desired voltage,

Keys worlds:

Five phase asynchronous machine, matrix converter, and of the strategy calculated modulation.

I. Introduction

Many-phases machines offer an interesting alternative to the reduction of constraints applied to the coils as switches. Indeed, multiplying the number of phases allows a splitting of power and thereby reducing tensions switched current given. Moreover, these machines can reduce the amplitude and increase the frequency of torque ripples, so that the mechanical load of the filter more easily.

Current progress of power electronics and the development of computing processors can consider a finer control of these machines by using PWM techniques.

The matrix converter topology is little known. So far, interest in this type of converters was rather academic in nature and thus there is no commercial product matrix converter, because of the complexity of its high command and its reduced voltage compared the conventional solution. However, we can consider the difficulties posed by the practical realization of the matrix converter in the pass due to the problem of switching current (lack of free wheel diodes) and protection of power circuits.

II. Matrix converter modeling

The matrix converter provides direct conversion alternative - alternative without intermediate circuit continuous characterizing conventional converters (rectifier - inverter). Its function is to ensure the transition adjustment of electric power from the source to the receiver.

Thus it is vital to establish the model order which is derived from a knowledge model of the converter, using Petri networks, the functions of connection and conversion functions.

II.1. Structure of the matrix converter:

The matrix converter is a static frequency converter, which is the main feature of the conventional rectifier converters - UPS. It helps to have many phase output voltage variable amplitude and frequency from an input of a system of many phase voltages fixed supply network.

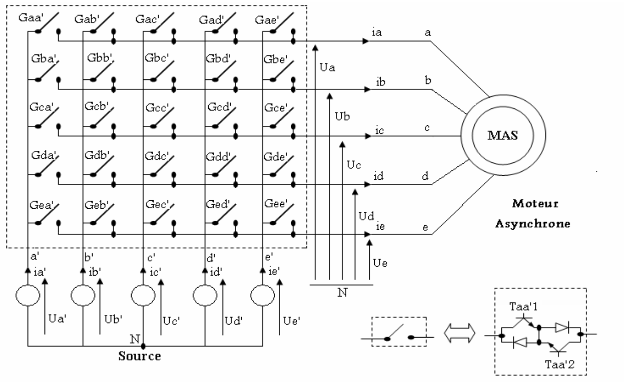

Figure (1): Schematic diagram of the matrix converter.

This converter is characterized by a topology matrix of twenty-five switches (matrix [5x5]), as the five phases of inputs in the network are interconnected to the five phases of the converter output through power bidirectional switches.
The switch matrix converter can be modeled by two diodes and two transistors greatly reduced the number of possible configurations 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:

- 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 realizable: a source of non-zero voltage can not be implemented in short circuit, a source of non-zero current can not be implemented in open circuit.

Finally we deduce that for each cell a single switch must be closed, is reducing the number of possible configurations 5^5.

II.2 How a cell of the matrix converter:

Considering the functional symmetry of switching cells, and compared with the order, the study of the matrix converter is limited to the study of a cell switching. In each cell there are five possible configurations that are characterized by electricity.

II. 3 Modeling for the command:

III. Strategy for control of one converter Raster:

We will study three modulation strategies adapted to the matrix converter.

The analysis of these strategies will be based on the plug and adjusting the rate of harmonic output voltages of the matrix converter.

III. 1 Definition of the fictitious intermediate voltage:

The principle of controlling the matrix converter is based on the analogy with the converter circuit with an indirect intermediary fictitious (rectifier-inverter).

So to talk about the complexity of command matrix converter, one takes advantage of the conventional converter voltage by introducing a fictitious intermediate and studied separately the two parts: rectifier - inverter.

The fact that at any given time, it has at least one phase of the voltage which is positive and at least one other phase is negative relative to neutral food, you can choose potential shadow U^+ et U^- as :

$$U_d = U^+ - U^- \qquad \textbf{(1)}$$

U_d : intermediate voltage is called fictitious.

The purpose of introducing the fictitious intermediate voltage is to separately analyze and optimize the recovery and ripple, and thus the separate development of algorithms order.

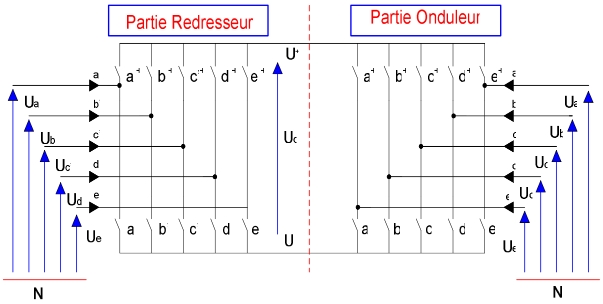

Figure (2): Model of matrix converter circuit with intermediate fictitious.

III. 2 Study of the rectifier:

For recovery, the harmonic spectrum of input is very important. So it is necessary to use a modulation function to provide the input current sinusoidal form, while retaining the equivalent power transmitted via the intermediate circuit.

In order to easily implement the reorganization, we define the matrix of functions which allows recovery of the link between the supply voltages and the intermediate shell as follows:

$$\begin{bmatrix} U^+ \\ U^- \end{bmatrix} = \left[M_R\right] . \begin{bmatrix} U_{a'} \\ U_{b'} \\ U_{c'} \\ U_{d'} \\ U_{e'} \end{bmatrix} \qquad \textbf{(2)}$$

Noted that:

$$\left[M_R\right] = \begin{bmatrix} a'^+ & b'^+ & c'^+ & d'^+ & e'^+ \\ a'^- & b'^- & c'^- & d'^- & e'^- \end{bmatrix}$$

$[M_R]$: matrix is said to function recovery.

Considering the symmetry found in a recovery period, we can distinguish ten intervals.

III. 3 Study of the inverter:

It will introduce, as ucmk modulations which can take continuous values between 0 and 1, to define the modulation matrix [M0]. The latter enables to link the potential intermediate fictitious and the output voltages of the matrix converter, as follows:

$$\begin{bmatrix} U_a \\ U_b \\ U_c \\ U_d \\ U_e \end{bmatrix} = \left[M_0\right] . \begin{bmatrix} U^+ \\ U^- \end{bmatrix} \qquad \textbf{(3)}$$

With:

$$\left[M_0\right] = \begin{bmatrix} U_{cm1} & 1 - U_{cm1} \\ U_{cm2} & 1 - U_{cm2} \\ U_{cm3} & 1 - U_{cm3} \\ U_{cm4} & 1 - U_{cm4} \\ U_{cm5} & 1 - U_{cm5} \end{bmatrix}$$

$[M_0]$: is called modulation matrix.

Taking into account the two blocks rectifier - inverter is obtained:

$$\begin{bmatrix} U_a \\ U_b \\ U_c \\ U_d \\ U_e \end{bmatrix} = [M_0][M_R].\begin{bmatrix} U_{a'} \\ U_{b'} \\ U_{c'} \\ U_{d'} \\ U_{e'} \end{bmatrix} \qquad \textbf{(4)}$$

With:

$$[F_g] = [M_0].[M_R]$$

We come finally to characterize the matrix [FG] to define the complete algorithm for frequency conversion such as:

III. 4 Modulation of voltage intermediate shell:

The reference voltage input stages are defined as follows:

$$\begin{cases} U_{1ref} = U_m \sin(\omega_0 t) \\ U_{2ref} = U_m \sin(\omega_0 t - 2.\pi/5) \\ U_{3ref} = U_m \sin(\omega_0 t - 4.\pi/5) \\ U_{4ref} = U_m \sin(\omega_0 t + 4.\pi/5) \\ U_{5ref} = U_m \sin(\omega_0 t + 2.\pi/5) \end{cases} \qquad \textbf{(5)}$$

With: $\omega_0 = 2\,\pi\, f_o$

The determination of ripple functions (functions of the standard reference) is the modulation of the voltage intermediate fictitious given previously:

$$u_{cmk} = r.\cos(\Phi)\ .\sin\left(\omega_0\, t - 2(k-1)\frac{\pi}{5}\right) + \frac{1}{2} \qquad \textbf{(6)}$$

With:

u_{cmk} : Modulation function or function reference standard

r : Rate of modulation.

ω_0 : pulse voltages of reference phase output.

k = 1, 2, 3, 4, 5.

III. 5 Strategies for controlling the matrix converter the calculated modulation strategy:

In this section, we propose a PWM strategy using the model of matrix converter command.

Function Generator Connection:

The functions of the converter output must follow the reference voltages imposed on the screen.

- Let $U_{a'}$, $U_{b'}$, $U_{c'}$, $U_{d'}$ and $U_{e'}$ supply voltages of the converter
- Let U_a, U_b, U_c, U_d and U_e tensions reference output converter.

$$\begin{cases} U_a = r.U_m \sin(\omega_s t) \\ U_b = r.U_m \sin(\omega_s t - 2.\pi/5) \\ U_c = r.U_m \sin(\omega_s t - 4.\pi/5) \\ U_d = r.U_m \sin(\omega_s t + 4.\pi/5) \\ U_e = r.U_m \sin(\omega_s t + 2.\pi/5) \end{cases} \qquad \textbf{(11)}$$

The expressions of the converter voltage converter are expressed as follows:

$$\begin{bmatrix} U_a \\ U_b \\ U_c \\ U_d \\ U_e \end{bmatrix} = \begin{bmatrix} F^g_{a'a} & F^g_{b'a} & F^g_{c'a} & F^g_{d'a} & F^g_{e'a} \\ F^g_{a'b} & F^g_{b'b} & F^g_{c'b} & F^g_{d'b} & F^g_{e'b} \\ F^g_{a'c} & F^g_{b'c} & F^g_{c'c} & F^g_{d'c} & F^g_{e'c} \\ F^g_{a'd} & F^g_{b'd} & F^g_{c'd} & F^g_{d'd} & F^g_{e'd} \\ F^g_{a'e} & F^g_{b'e} & F^g_{c'e} & F^g_{d'e} & F^g_{e'e} \end{bmatrix} . \begin{bmatrix} U_{a'} \\ U_{b'} \\ U_{c'} \\ U_{d'} \\ U_{e'} \end{bmatrix} \qquad \textbf{(12)}$$

Regarding the algorithm for controlling this strategy, we follow exactly the same procedure as the previous strategy.

Five cases are presented:

$$\begin{cases} F^g_{a'} = F^g_{c'} = F^g_{d'} = 0 \\ F^g_{a'} = F^g_{b'} = F^g_{d'} = 0 \\ F^g_{b'} = F^g_{d'} = F^g_{e'} = 0 \\ F^g_{b'} = F^g_{c'} = F^g_{e'} = 0 \\ F^g_{a'} = F^g_{c'} = F^g_{e'} = 0 \end{cases} \qquad \textbf{(13)}$$

To determine the function of connecting discontinuous constituent elements of the conversion matrix F that attack matrix converter switches can be compared with the generating functions for carriers.

IV. Simulation and results:

To study the performance of the matrix converter by the three modulation strategy and it has made the study of the harmonic spectrum of output voltages of the matrix converter. For the simulations on a sample taken as the output voltage of the converter Va phase **'a'.**

In Figure **(3)** on the spectra represented harmonic voltage Va for an output frequency of the converter equal to 50 Hz, using the modulation index m = 21 and the modulation rate r = 0.8.

Then in the end, we outlined the characteristics of rf as a function of modulation rate r for a frequency for = 50 Hz and a modulation index equal to 21, in figure **(4).**

rf is defined as the ratio between the value of fundamental voltage V_a (V_{afond}) on Udmin.

Interpretation of simulation results:

From the simulation results of harmonic spectra of voltage Va are as follows:

1. For values of the modulation index m, there is no symmetry and thus there are odd and even harmonics.
2. The harmonic voltages are grouped into families centered around multiples of the frequency of the carrier (for fp = m).
3. The first family centered around the frequency for m is the largest in terms amplitude, for the first two methods, followed by another family centered author of 2m for the frequency lower than the first for the third method.

East to the characteristics of harmonic and rates depending on the rf modulation rate r:

The rate decreases when the harmonic modulation rate r increases in the linear rf in the three following methods:

- La modulation MLI calculée (r =0 à0.9).
  Δthdi = 47.8%

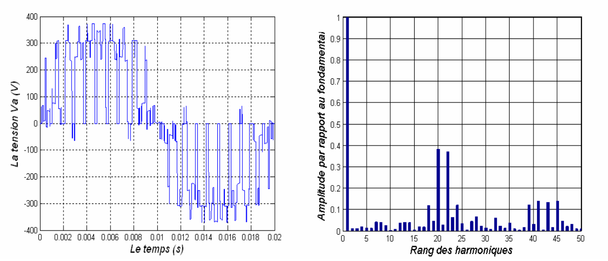

Figure (3): The harmonic spectra of output voltage Va at a frequency output f0 = 50 Hz and r = 0.8, m = 21.

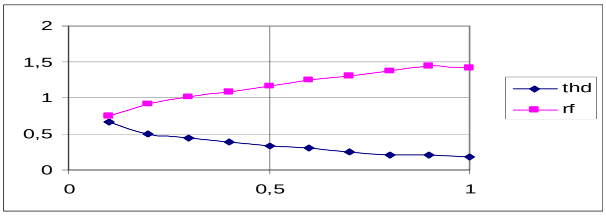

Figure (4): The characteristics of the rate of harmonic rf and according rate modulation r

V. CONCLUSION

In this article, the strategy for controlling the matrix converter is:

The strategy of calculated modulation PMW

The voltages are grouped into families centered around the frequencies of one and multiple twice that of the carrier for the PWM modulation strategy calculated.

The injection of harmonic multiples of five in the reference voltages can increase the linear tuning voltage without any increase performance times for the conduct of the asynchronous machine pentaphasée.

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