Study of output voltages of a matrix converter feeding an five AC - induction Machine Using the strategy PWM modulation to five intervals

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Abstract:

In this article we present an analytical study with the use of the strategy PWM modulation to five intervals 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 *PWM modulation to five intervals*.

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.

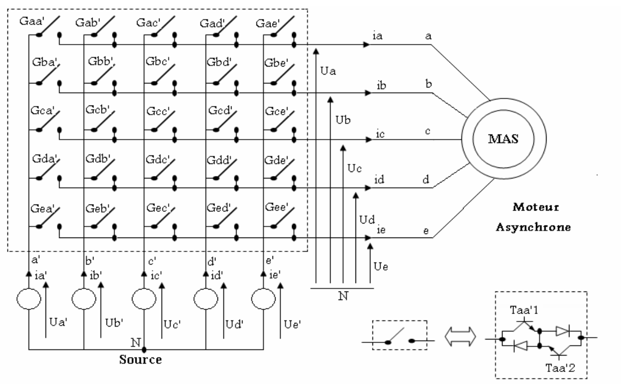

Figure (1): Schematic diagram of the matrix converter.

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 switc 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.

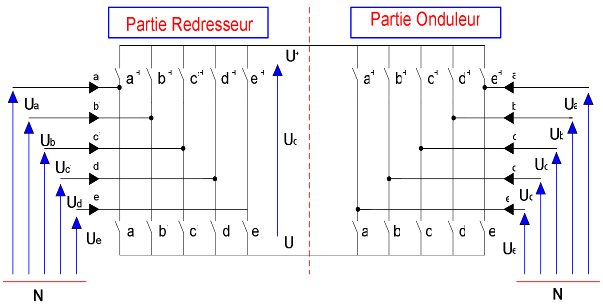

Figure (2): Model of matrix converter circuit with intermediate fictitious.

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:

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

Noted that:

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

$[M_R]$: 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:

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

With:

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

$[M_0]$: is called modulation matrix.

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

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

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:

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

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:

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

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 Strategy for controlling the matrix converter is PWM modulation to five intervals:

The MLI is a well established technique for pulse converters. We see that for the control of each phase matrix converter output power must be switched at each stage of entry during a determined period of pulsation. This also applies if we consider the transfer in the opposite direction, for switching the input phases to the phases of output.

We must therefore divide the period of pulsation in five intervals. To do so, in fact, employ a technique similar to that of conventional PWM modulators.

The saw tooth signal of reference will be compared to a control signal. In this way we obtain a binary signal output by phase, indicating the state of power switch.

On taking account of previous equations, we define the reference signals τ_X as follows:

$$\begin{cases} \tau_{X1} = F^g_{a'a} = a'^{+}\ U_{cm_1} + a'^{-}\ (1 - U_{cm_1}) \\ \tau_{X2} = \tau_{X1} + b'^{+}\ U_{cm_1} + b'^{-}\ (1 - U_{cm_1}) \\ \tau_{X3} = \tau_{X2} + c'^{+}\ U_{cm_1} + c'^{-}\ (1 - U_{cm_1}) \\ \tau_{X4} = \tau_{X3} + d'^{+}\ U_{cm_1} + d'^{-}\ (1 - U_{cm_1}) \end{cases} \quad \textbf{(7)}$$

From the equation **(6)**, the ripple u_{cm1} for phase **a** can be written as follows:

$$u_{cmi} = \frac{U_{iref}}{U_{d\,min}} \cos(\Phi) + \frac{1}{2} \quad \textbf{(8)}$$

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 U_{dmin}.

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:

- *PWM modulation to five intervals* (r =0 à0.8).
Δthdi = 47%

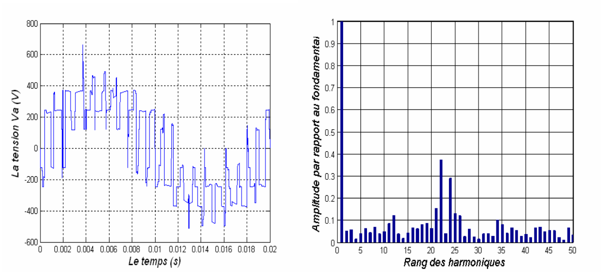

Figure (3): The harmonic spectra of output voltage Va at a frequency output f0 = 50 Hz and r = 0.8, m = 21.

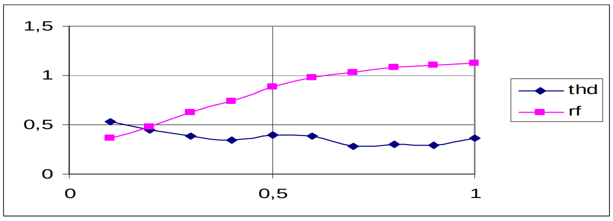

Figure (4): The characteristics of the rate of harmonic rf and according rate modulation r

V. CONCLUSION

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

The strategy of PWM modulation to five intervals

The harmonic voltages are grouped into families centered around multiples of the frequency of the carrier (for fp = m) for the modulation strategy MLI five intervals.

VI. References

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