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# Modelling and Control of Matrix Converter by Two Methods

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**Abstract**

This article presents a comparative study of two control strategies, namely Venturini and Venturini optimum. Both methods were applied to a three-phase RL-fed matrix converter, to illustrate the performance of each and to emphasize the similarities and differences between them. From the results of the simulation, with reference to the output voltage, the simulation of the three-phase matrix converter supplying an RL load was carried out using the "Matlab® / Simulink®" software. This platform makes it possible to simulate dynamic systems in a simple technique and in the graphic environment.

***Key words:*** *Matrix converter; RL load; Venturini & Alesina; Venturini & Alesina optimum*.

**Résumé**

Cet article présente une étude comparative de deux stratégies de contrôle, à savoir Venturini et Venturini optimum. Les deux méthodes ont été appliquées à un convertisseur matriciel triphasé alimenté en charge RL, dans le but d'illustrer les performances de chacune et de souligner les similitudes et les différences entre elles. A partir des résultats de la simulation, en référence à la tension de sortie, la simulation du convertisseur matriciel triphasé alimentant une charge RL a été réalisée à l'aide du logiciel "Matlab® / Simulink®". Cette plateforme permet de simuler les systèmes dynamiques dans une technique simple et dans le milieu graphique.

***Mots-clés :*** *Convertisseur matricielle ; charge RL ; Venturini & Alesina ; Venturini & Alesina optimum.*

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## 1. Introduction

The matrix converter is a forced commutated that contains nine bidirectional switches when providing energy conversion between source and load without using an energy storage element, that is to say, direct AC-AC conversion [1],[2].

The greatest essential characteristics of MCs are as follows:

- A simple and compact power circuit.
- Generation of load voltage with arbitrary amplitude and frequency.
- Sinusoidal input and output currents.
- Operation with unity power factor.
- Regeneration ability. These highly attractive characteristics are the reason for the tremendous interest in this topology.

These ideal characteristics can be fulfilled by matrix converters and this is the reason for the tremendous interest in the topology.

The object of this paper is to present a detailed comparative study of the two different scalar approaches namely, Venturini and Venturini optimum, when applied to the control of RL load. Performance response with respect to both techniques. This will enable us to identify the merits of each them in order to make a judicious choice for their use in matrix converter control applications.

## 2. Theory Of The Matrix Converter

The basic diagram of a three-phase / three-phase matrix converter shown in Figure .1 consists of 9 bidirectional current and voltage switches connecting the three input phases to those of the load, to model the MC a conversion matrix defined in equation (1) and based on the connection function is used. The connection function, which is defined in equation (2), gives the state of bidirectional switch [3],[4].

$$S_{ij} = \begin{bmatrix} S_{Aa} & S_{Ab} & S_{Ac} \\ S_{Ba} & S_{Bb} & S_{Bc} \\ S_{Ca} & S_{Cb} & S_{Cc} \end{bmatrix} \quad (1)$$

$$S_{jk} = \begin{cases} 1 & \text{if the switch } S_{jk} \text{ is on} \\ 0 & \text{if the switch } S_{jk} \text{ is off} \end{cases}$$

Where

$$j \in \{A \quad B \quad C\},\ \mathrm{k} \in \{a \quad b \quad c\} \quad (2)$$

For a matrix converter, only one switch each switching cell must be on.

$$S_{ja} + S_{jb} + S_{jc} = 1,\ j \in \{A, B, C\} \quad (3)$$

The output voltage $V_s$ in any time presented as:

$$V_s = \begin{bmatrix} V_A \\ V_B \\ V_C \end{bmatrix} = \left[S_{jk}\right]^T \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \quad (4)$$

The input MC currents $I_{in}$ also defined as:

$$I_{in} = \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \left[S_{ij}\right]^T \begin{bmatrix} I_A \\ I_B \\ I_C \end{bmatrix} \quad (5)$$

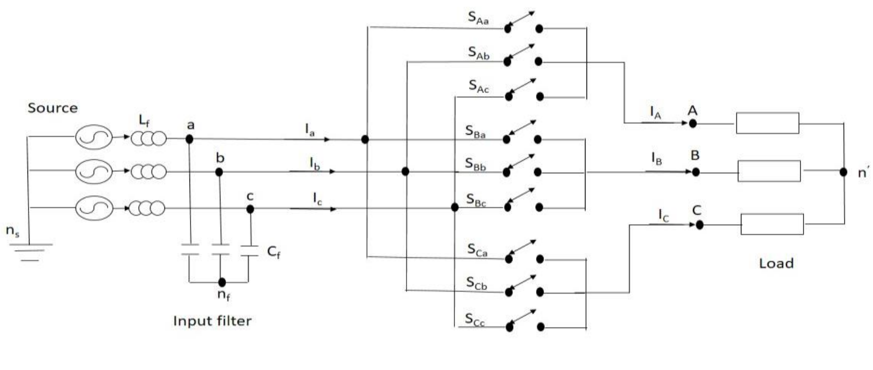



**Figure. 1**. Topologie of matrix converter.

Let be the vector of the input voltages given as:

$$[V_{abc}] = V_{im} \begin{bmatrix} \cos(\omega_i t) \\ \cos(\omega_i t + \frac{2\pi}{3}) \\ \cos(\omega_i t + \frac{4\pi}{3}) \end{bmatrix} \quad (6)$$

and the vector $[V_{ABC}]$ of the desired output voltages

$$[V_{ABC}] = V_{om} \begin{bmatrix} \cos(\omega_o t) \\ \cos(\omega_o t + \frac{2\pi}{3}) \\ \cos(\omega_o t + \frac{4\pi}{3}) \end{bmatrix} \quad (7)$$

The problem consists in finding a matrix M, known as the modulation matrix, such that

$$[V_{ABC}] = [M][V_{abc}] \quad (8)$$

Input and output current related by

$$[I_{abc}] = [M]^T [I_{ABC}] \quad (9)$$

Where $[M]^T$ represents the transposed matrix of $[M]$.
The development of the equation (8) gives:

$$\begin{bmatrix} V_A \\ V_B \\ V_C \end{bmatrix} = \begin{bmatrix} m_{Aa} & m_{Ab} & m_{Ac} \\ m_{Ba} & m_{Bb} & m_{Bc} \\ m_{Ca} & m_{Cb} & m_{Cc} \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \quad (10)$$

Where $m_{ij}$ are the modulation coefficients, and at any time

$$0 \le m_{ij} \le 1 \quad (11)$$

## 3. Venturini & Alesina method

A first resolution found by using the duty-cycle matrix approach, has been proposed in [1]. This strategy permits the control of the output voltages and input power factor, and can be summarized in the following equation, valid for unity input power factor $(\alpha_i = \beta_i)$ [5], [8].

Is a control method of the matrix converter based on an approach mathematical.

The switches are closed cyclically so that the sequence k has:

$$t_1^k + t_2^k + t_3^k = T_{ech} = \frac{1}{f_{ech}} \quad (12)$$

The equation is presented here:

$$V_o^k = V_A \, . \, t_1^k + V_B \, . \, t_2^k + V_C \, . \, t_3^k \quad (13)$$

The use of the Venturini method leads us to a maximum value of 0.5 for the transformation ratio q that the converter can.

The elements of the connection matrix $[M(t)]$ , are defined as follows reach [1].

$$m_{kj} = \frac{t_{kj}}{T_s} = \frac{1}{3}\left[1 + \frac{2V_{ik}V_{jo}}{V_i^2}\right] \quad (14)$$

## 4. Venturini & Alesina optimum method

The maximum output voltage has been increased to 86% of the voltage input by changing the desired output voltage, including the third harmonic of the voltage and that of the desired output [2]. The pace of the desired output voltage travels almost the entire envelope of the input voltage. This harmonic of order three will be eliminated in a charge phase; in the same way as the third order harmonic addition in an inverter [9], [10].

The elements of the connection matrix $[M(t)]$ , are defined as follows:

$$m_{kj} = \frac{t_{kj}}{T_s} = \frac{1}{3}\left[1 + \frac{2V_{ik}V_{jo}}{V_i^2} + \frac{4q}{2\sqrt{3}} \, . \sin(\omega_i t - B_k).\sin(3\omega_i t)\right] \quad (15)$$

## 5. Simulation Results and discussion

The simulation of this modulation method of the matrix converter was performed on MATLAB/ SIMULINK. The following curves (figures -a- to -e-) represent the results obtained which have a switching period of 5 KHz and a 50Hz output frequency. These curves represent the output voltage, input and output current of the matrix converter on an inductive load (R-L). Figure 2 shows a good performance in terms of the output voltage and reference relative to the network neutral, output voltage and reference relative to the load neutral, input current filtered, unfiltered and input voltage, output current shows a sinusoidal waveform, while the output voltage following the reference. Input voltage and input current are at the same phase, while output current of matrix converter is lag from output phase voltage due to inductive load. Which are occurred on input current during commutation have been smoothed using a small three input filter. These results prove that the matrix converter can draw current in the unity displacement factor from mains at any load. In addition to, pulses with the switching frequency. The only major drawback is that the output voltage of this method is limited to 50% of the input voltage.

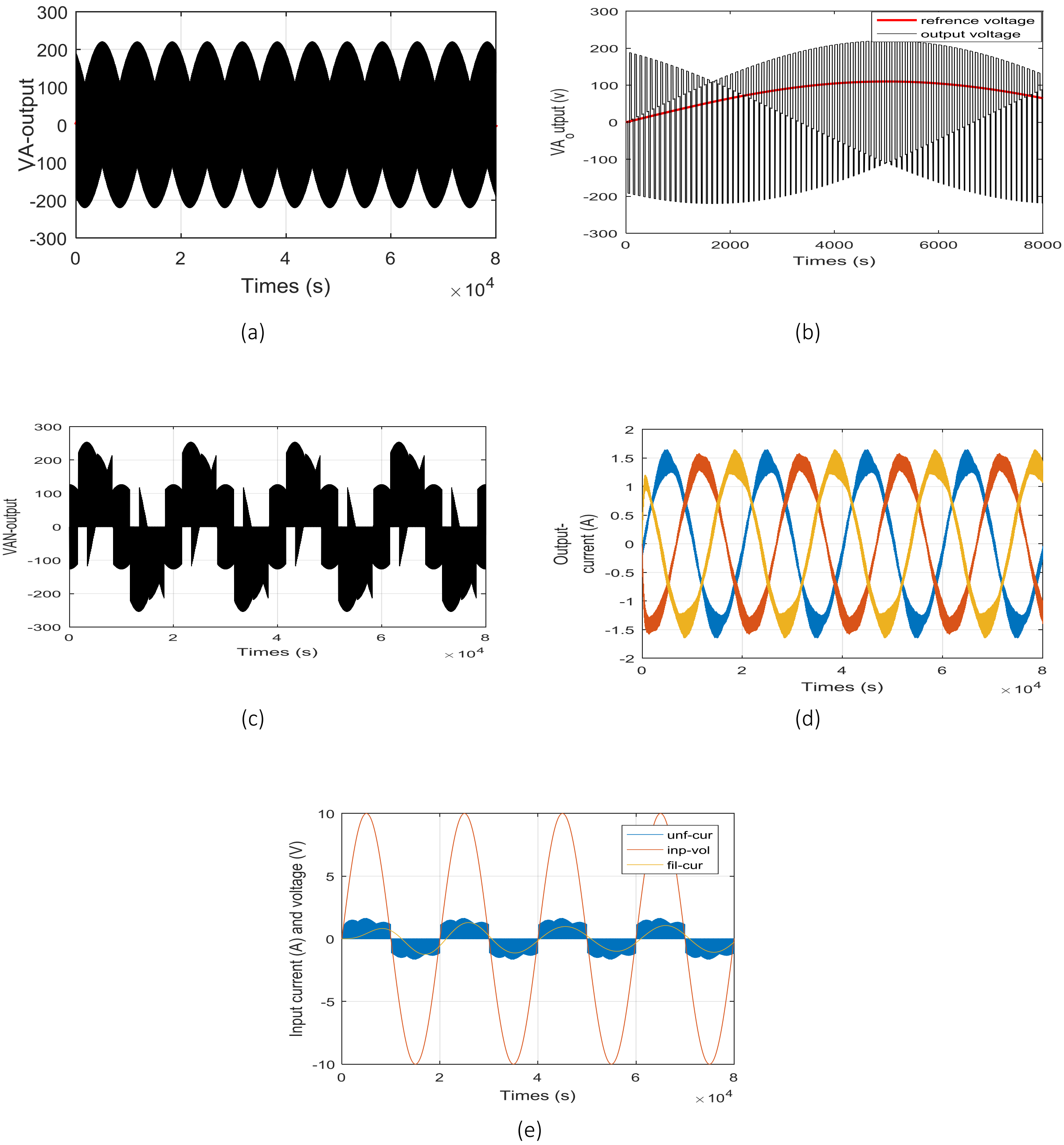
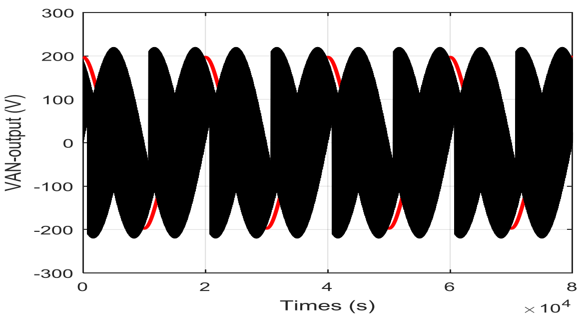
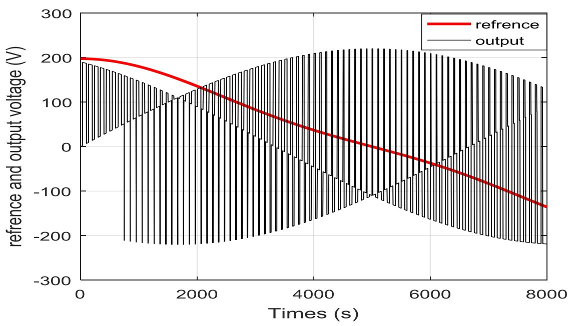



**Figure. 2.** Venturini simulation results, (a) output voltage and reference relative to the network neutral, (b) zoom of the output

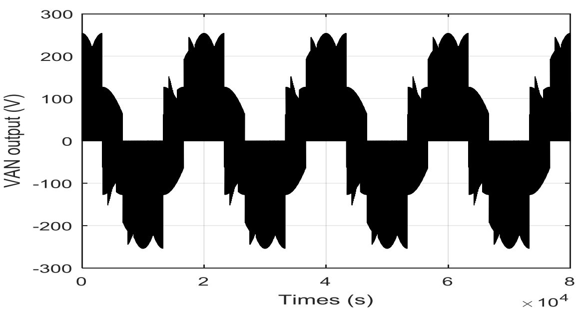
Figure 3 shows all advantages of this method input and output current and voltage are sinusoidal , Input voltage and input current are at the same phase, the ratio of transformation it 86.6%.



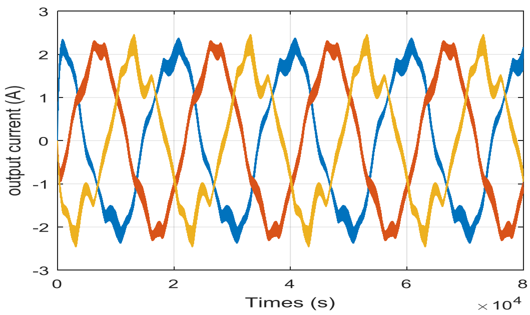

(a)



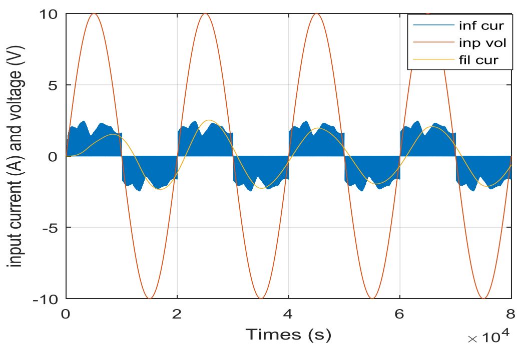

(b)




(c)




(d)




(e)

**Figure 3.** Venturini optimum simulation results, (a) output voltage and reference relative to the network neutral, (b) zoom of the output voltage, (c) output voltage relative to the load neutral,(d) output current , (e) input current unfiltered ,filtered and voltage.

✓ Comparison between the two methods

- The two methods in general gives close results. The reference voltage is respected, but the optimum method is better in this point because the ratio of transformation is 0.86.
- Both The input, output current and voltage are sinusoidal for the two methods.
- The input displacement factor unitary $\cos(\phi) = 1$.
- The two methods are easy to implement.

## 6. Conclusion

In the present paper, the comparative performance study of two different control strategies applied to matrix converter is presented. The first strategy is performed by the Venturini method and the second is from optimum venturini control. However, two methods Venturini and venturini optimum are simple and easy to implement, but the venturini method makes it possible to generate sinusoidal voltages, its disadvantageous is limit of the transformation ratio, which is not exceeded 0.5. On the other hand, the optimum method of the transformation ratio is 0.86. The optimum method is preferred.

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