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Modeling of Three Phase Matrix Converter, Performance and Analysis

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ABSTRACT: The matrix converter is an array of controlled semiconductor switches that connects directly the three-phase source to the three-phase load. This converter has several attractive features that have been investigated in the last two decades. In the last few years, an increase in research work has been observed, bringing this topology closer to the industrial application. In this paper, a matrix converter (MC) which makes directly AC-AC power conversion is modeled using Matlab&Simulink and its working principles are analyzed. The gate signals of the power switches of MC are produced using Optimum Amplitude-Venturini Modulation (OAVM) method. This method provides the amplitude of output voltage up to 86.6% of input voltage, and unity fundamental displacement factor at the input regardless of the load displacement factor. The simulation results obtained from the model at various operating conditions are presented. These results prove effectiveness of the proposed matrix converter model with a unity input power factor. Consequently, the designed Matlab&Simulink model can be confidently used in the construction stage of the OAVM method based matrix converter.

I.INTRODUCTION

Most of all industrial applications are depended on ac-ac power conversion. The ac-ac converters are widely used in the industry applications because of its ease of use and provide the output voltage and current of desired magnitude. The ac-ac converter takes power from one ac system and delivers it to other ac system with the waveform having different amplitude, frequency, and phase. There are two ac-ac converter i.e. indirect converters and direct converter. Indirect converter are those converters which utilized. A dc link between the two ac systems and direct converters are those which provide direct conversion. MC provides the directs conversion from ac to ac. Matrix converter firstly introduced in 1976 started to improving after papers of venturini and alesina in 1980. The proposed method by these authors is known as the venturini method or the direct transfer function approach. In this method get drive signal for the 9 bi-directional switches are calculated to generate variable-frequency and/or variable-amplitude sinusoidal output voltages from the fixed-frequency and the fixed-amplitude input voltages. The matrix converter has several advantages over traditional rectifier-inverter type power frequency converters. It provides sinusoidal input and output waveforms, with minimal higher order harmonics and no sub harmonics; it has inherent bi-directional energy flow capability; the input power factor can be fully controlled. Last but not least. It has minimal energy storage requirements which allows to get rid of bulky and life time-limited energy-storing capacitors. But the matrix converter has also some disadvantages. First of all it has a maximum input-output voltage transfer ratio limited to ≡87% for sinusoidal input and output waveforms. It requires more semiconductor devices then a conventional ac to ac indirect power frequency converter. Since know monolithic bi-directional switches exist and consequently discrete uni-directional devices, variously arranged have to be used for each bi-directional switch. Finally, it is particularly sensitive to the disturbances of the input voltage system. The other advantages of three phase to three phase direct matrix converter is compact design due to the lack of dc link components for energy storage, controllable of input. Displacement factor regardless of load. But the physical realization of the MC is very difficult. And the number of the

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devices in the power circuit is higher than that of the inverter. Therefore, it is crucial to obtained and effective model and to test it before constructing a working prototype of the MC. In this work, and effective model of the MC is developed by using MATLAB/SIMULINK in order to compensate mentioned necessity. The basic concepts of MC is briefly given in a clear form. OAVM method is used to produce the gate signals driving bi-directional power semiconductors, and a maximum voltage transfer ratio (0.866) was obtained. An input filter is used at input side of converter. It smooth's distortion of the input current around the switching frequency and eliminates the generation of over voltage produced during commutations of current due to the presence of the short circuit reactance of any real power supply. The working principles of MC producing the output voltages at various amplitude and frequency are analyzed. Also simulation results of OAVM method base matrix converter are given.

II.THE BASIC TOPOLOGY

The matrix converter consists of 9 bi-directional switches that allow any output phase to be connected to any input phase. The circuit scheme is shown in figure1. The input terminals of the converters are connected to a three phase voltage-fed system, usually the grid, while the output terminal are connected to a three phase current- fed system, like an induction motor might be . The capacitive filter on the voltage-fed side and the inductive filter on the current –fed side represented in the figure1. Its are intrinsically necessary. Their size is inversely proportional to the matrix converter switching frequency. The matrix converter has an array of m×n bi-directional power switches. Each bi-directional switch is composed of two IGBTs and two fast diodes connected anti-parallel. Theoretically the number of input phases, m must be at least three, and the number of output phases, n can be chosen from one to infinity. This is the most important matrix converter topology from a practical point of view. A matrix converter is an unlimited frequency changer, which can generate both smaller and bigger output frequency than input frequency of the converter. 3-phase ac Source matrix converter.

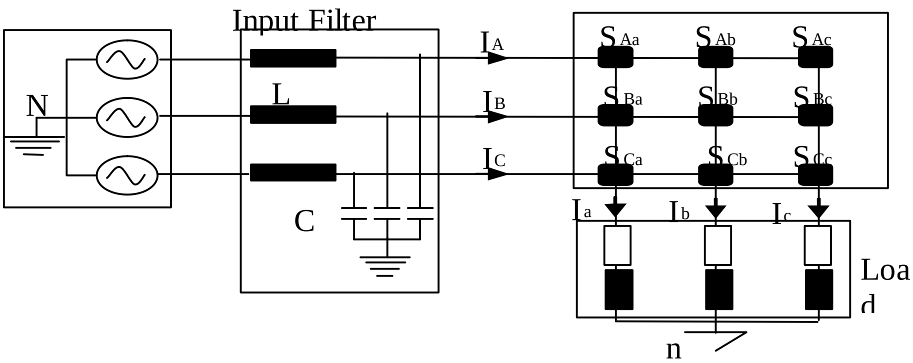

Fig:1 - circuit of a 3×3 matrix converter

Each switch is characterized by a switching function, defined as follows and can connect or disconnect phase *K* of the input stage to phase *j* of the load.

$$S_{kj}(t) = \begin{cases} 0\ Switch, S_{kj}\ is\ open \\ 1\ Switch, S_{kj}\ is\ closed \end{cases} \quad (1)$$

K= {A, B, C}, J= {a, b, c}

Output voltages can be synthesized by switching according to a proper combination of these switches. Control of the matrix converter must comply with the following basic two rules. Firstly, any two input terminals should never be connected to the same output line to prevent Short-circuit, because the MC is fed by a voltage source. The other is that,

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an output phase must never be open-circuited, Owing to the absence of a path for the inductive load current which leads to the over-voltages. The above two constraints Can be expressed by (2)

$$m_{Aa}(t) + m_{Ba}(t) + m_{Ca}(t) = 1$$
$$m_{Ab}(t) + m_{Bb}(t) + m_{Cb}(t) = 1$$
$$m_{Ac}(t) + m_{Bc}(t) + m_{Cc}(t) = 1 \qquad (2)$$

When these rules are provided, the 3 x 3 matrix converter can allow only 27 different switching states among the possible 512 switching combinations.

III.MODULATION TECHNIQUES

The purpose of these modulation techniques is to change the voltage transfer ratio. There are different types of Modulation techniques available which can be used for producing the gating signals. These are Alesina –Venturini modulation technique, Scalar modulation technique, Space vector modulation technique, indirect modulation technique. The main modulation techniques which have wide applications are Venturini modulation technique and the space vector modulation technique. In this paper space vector modulation is used for producing the gating signals for three phase matrix converter.

IV.CONTROL SCHEME OF THREE PHASE MATRIX CONVERTER

The object of the modulation strategy is to synthesize the output voltages from the input voltages and the input currents from the output currents matrix converter can be represented by a 3 by 3 matrix form because the nine bidirectional switches can connect one input phase to one output phase directly without any intermediate energy storage elements. Therefore, the output voltages and input currents of the matrix converter can be represented by the transfer function T and the transposed T^T such as:

$$V_0 = T.V_1$$

$$\begin{bmatrix} V_A \\ -V_B \\ V_C \end{bmatrix} = \begin{bmatrix} S_{aA} & S_{bA} & S_{cA} \\ S_{aB} & S_{bB} & S_{cB} \\ S_{aC} & S_{bC} & S_{cC} \end{bmatrix} . \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}.$$

$$I_1 = T^T.I_0$$

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} S_{aA} & S_{aB} & S_{aC} \\ S_{bA} & S_{bB} & S_{bC} \\ S_{cA} & S_{cB} & S_{cC} \end{bmatrix} . \begin{bmatrix} I_A \\ I_B \\ I_C \end{bmatrix}.$$

Where V_a, V_b and V_c are input phase voltages, V_A, V_B and V_C are output phase voltages, I_a, I_b and I_c are input currents and I_A, I_B and I_C are output currents.

V.MATLAB& SIMULINK MODEL OF 3× 3 MATRIX CONVERTER

A global Matlab&Simulink model of matrix converter which includes models of three-phase source, filter, reference voltage, load, and especially the switching pattern is given in Fig. 4. As a result, input and output currents, output phase voltages with respect to N (V_{aN}, V_{bN}, V_{cN}) and n (V_{an}, V_{bn}, v_{cn}), output line-to-line voltages (V_{ab}, V_{bc}, V_{ca}) of matrix converter controlled with OAVM method are attained using this model.

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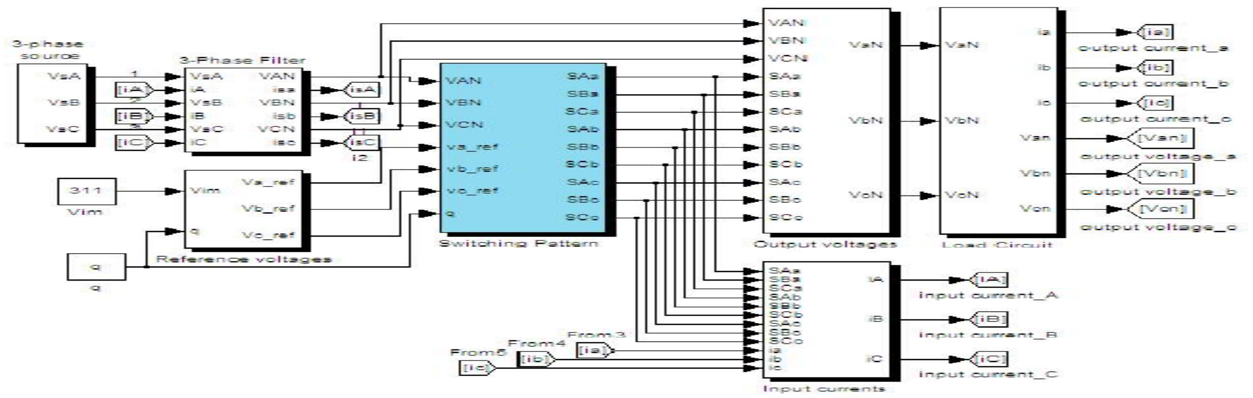


Fig.4.Matlab&Simulink model of the 3 x 3 matrix converter

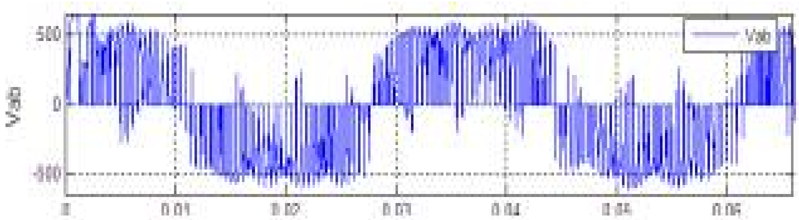
VI.SIMULATION RESULTS AND DISCUSSION

Parameter used in the developed simulation model have been given in table 1.Simulation of matrix converter has been performed to produce output with variable frequency from input with fixed frequency. In this paper, simulation results have been presented for only output frequencies of 30 and 60 Hz from an input of 50 Hz.

Table 1 Simulation Parameter

Source Voltage Amplitude	311 volts
Filter Inductance	3mH
Filter Capacitance	25µF
Filter Resistance	1Ω
Load Inductance	30mH
Load Resistance	10Ω
Input Frequency	50Hz
Voltage transfer ratio	0.8
Output Frequency	30 and 60 Hz

In Fig. 5(a) and Fig. 5(b), output line-to-line voltages for 30 and 60 Hz have been respectively given. As shown, these voltages have pulses with switching frequency but their averages constitute a sinusoidal waveform. That is, third-harmonic injection does not have a negative effect on the output line-to-line voltages.



(a)

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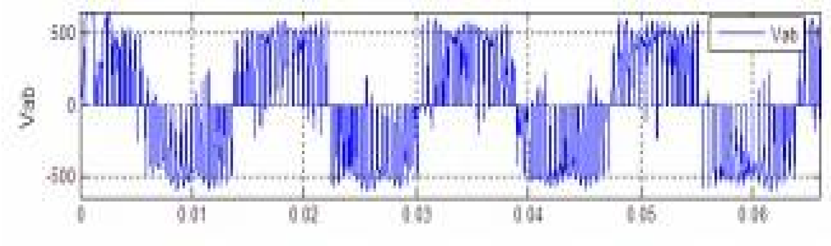
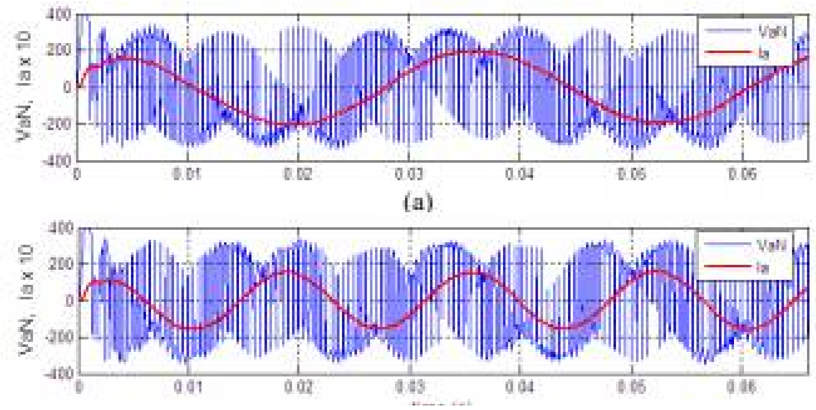


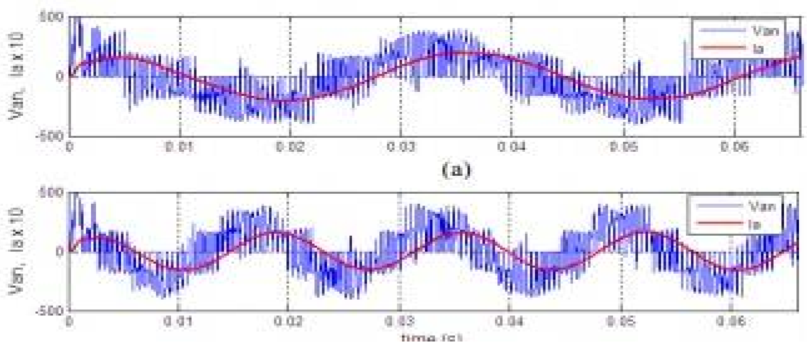
Time (s)
(b)

Fig 5. Output Line to Line Voltage (a) in 30 Hz (b) in 60 Hz



Time (s)
(b)

Fig 6. Output phase voltage with respect to star point of source and output current:
(a) in 30Hz (b) in 60Hz



Time(s)
(b)

Fig 7. Output phase voltage with respect to star point of load and output current:
(a) in 30Hz (b) in 60Hz

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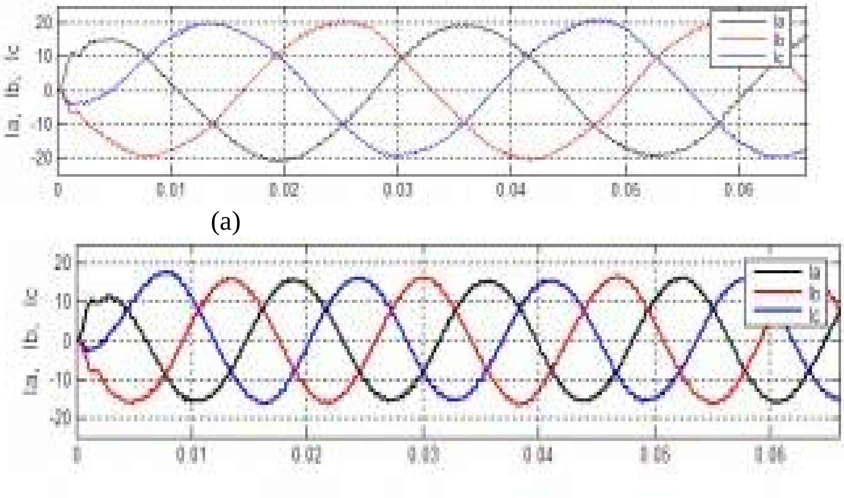
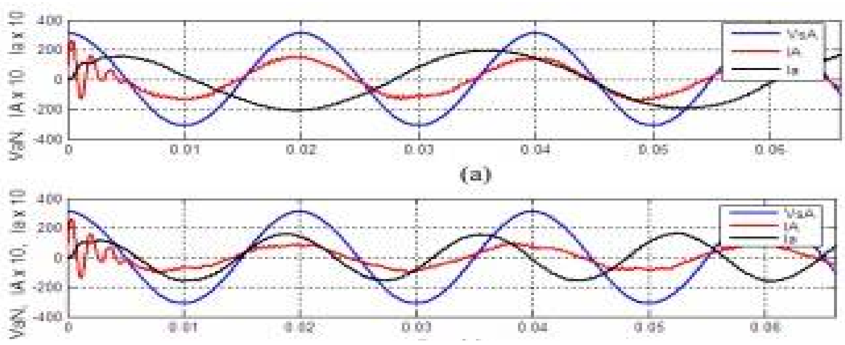


Time (s)
(b)
Fig 8. Three phase Output Current: (a) in 30Hz (b) in 60Hz

In Fig. 6(a) and Fig. 6(b), output phase voltage with Respect to neutral of source and output current have been shown at output frequencies of 30 and 60 Hz, respectively.
In Fig 7(a) and Fig. 7(b), output phase voltage with respect to neutral of load and output current have been shown. As understood from these figures, output phase voltages have pulses with 2 kHz frequency and average of its waveform is sinusoidal. Besides, output current is lag from output phase voltage due to inductive load. Three phase output currents have been illustrated at outputs of 30 Hz in Fig 8(a) and 60 Hz in Fig. 8(b). As shown, load currents are nearly a pure sinusoidal in the Two-frequency and there is a phase difference of 120° among the currents.

In Fig. 9, waveforms of source voltage, current drawn from source and load current which are obtained using by the implemented matrix converter model are given on the same axis. As understood from Fig. 9(a) and Fig. 9(b), both frequency of input voltage and input current is 50 Hz, even if frequency of output current is 30 Hz or 60 Hz.



Time (s)
(b)
Fig 9. Input voltage, Input Current and Output Current: (a) in 30Hz (b) in 60Hz

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. These results prove that the matrix converter can draw current in the unity displacement

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factor from mains at any load. In addition to, pulses with the switching frequency which are occurred on input current during commutation have been smoothed using a small three input filter.

VII.CONCLUSION

The working principle and analysis of the MC that Connects direct three-phase source to three-phase load and controlled with the OAVM method has been presented. Fundamental modulation strategies and fundamental mathematical equation of the MC have been presented clearly. Also, Modeling and simulation of the OAVM method, which can give an output voltage with maximum amplitude, has been implemented. The designed model has satisfactorily given the behavior of the MC including the impact of the input filter. The simulation results show that the modulation Algorithm provides a unity input displacement factor even if the load has an inductive characteristic. As a result, the Matlab&Simulink model presented can be confidently used in the construction stage of the matrix converter.

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