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Space Vector Pulse Width Modulation Strategy for Indirect Matrix Converters under Abnormal Input Voltage Conditions

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Abstract : *Matrix converter is a single-stage power conversion device for AC-AC without dc link of energy saving elements. Any disturbance in input voltage will be reflected immediately in output voltage. In this paper, different kinds of power electronic converters are introduced and then matrix converters are discussed completely comparing their position with other Alternating Current (AC) converters. Moreover, different types of switching methods in matrix converters are examined in terms of being direct or indirect and then Venturini algorithms and spatial vector modulation (SVM) are compared for use in this type of converters. The modified SVM strategy for matrix converter is presented under the abnormal, unbalanced and non-sinusoidal input voltage conditions that were calculated using the instantaneous size and phase of the input voltage vector to calculate the voltage modulation index and the input current phase angle. Moreover, the modified modulation strategy that is without extra control circuit could reduce influence of abnormal input voltages on output voltage; and voltage and symmetrical sinusoidal three-phase current can be obtained under the normal and abnormal input voltage. This study was conducted to provide a modulation technic in which, switching times of keys in inverter sector have an equation based on the number of considered sector that its reference voltage (Vref) is in the sector at that moment. To obtain such equation, dependence of modified SVM method on modulation index can be removed if it is necessary.*

Keywords: *Abnormal Input, Matrix Converter, Modulation Index, Modulation Strategy, Space Vector Pulse Width Modulation*

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I. Introduction

Matrix converter- a new generation of power electronic converters- is a power supply with variable frequency and amplitude that converts N input voltages to M output voltages directly and without using energy saving elements. In other words, matrix converter presents a complete silicon solution to convert ac to ac so that inverter does not use reactive energy saving elements contrary to classic rectifier systems. This converter consists of a matrix including two-way semiconductor switches that each of them connects input terminals to each of output terminals at the intersection of lines. Two-way switches should be able to block voltages with any polarization; they also should be able to pass current in any direction. Such arrangement of switches enables matrix converters for two-way energy conversion.Due to lack of energy saving elements, matrix converters have rapid response, high efficiency, small size, and integrated design, while these advantages are subjected to increase in number of two-way switches. Energy saving elements are expensive and occupy a large space; also it is difficult to control their stored energy in case of defect occurrence. In matrix converters, the wave and frequency are independent at two input and output sides. For instance, input can be ac three-phase while output is dc or both of them can be dc or ac. In addition, the number of input and output phases are independent from each other. Therefore, matrix converter is a comprehensive converter that can be substitute to all classic converters.

In case of modulation technics of matrix converter, it should be noted that matrix converter is supplied with a balanced sinusoidal voltage or a non-balanced non-sinusoidal voltage. Three methods are extensively used for developing modulation strategy in matrix converters with complete balanced and sinusoidal input voltage. The first modulation strategy is Alesina–Venturini that is based on analysis of conversion function; this method has been presented in [2, 3]. The second method is Spatial Vector Modulation (SVM) strategy including direct and indirect SVM methods that are presented in [4] and [5], respectively. SVM modulation strategy has been often used in matrix converter because of its advantages such as immediate understanding of required conversion or changing processes, simplified control algorithm and maximum voltage conversion ratio without adding third harmonic components [1]. Third method is based on punched double voltage input that is presented in [6]. According to the mentioned three methods, studies have tried to improve modulation methods under abnormal loads. In modulation method of "Venturini", some features of input supplying voltage in Duty-Cycle calculations are involved in order to prevent from effect of input disturbances on output voltage as much as possible [8]. It has been mentioned in this reference that matrix converter is a direct converter from alternating current energy to desirable output alternating current without DC link components. Therefore, converter output is directly affected by disturbance in input voltage. Many researchers have tried to solve this issue. Behaviors of matrix converter have also been examined under the conditions of inverted input voltage in this reference. A new compensating method based on Fuzzy Logic Control (FLC) has been recommended in which, blocked loop of output current is controlled to improve performance of MC output. Patrick Wheeler has reviewed matrix converters' structures in [1]; the most important control and modulation strategy have been discussed in this paper. He has tried to improve performance and solve problems related to matrix converter improving existing technics. In this reference, two-way switches have also been described as well and single switching module has been suggested. Majority of expressed subjects in his research are related to practical issues in practical applications, i.e. protection against extra voltages and use of filters.

II. Implementation of spatial vector modulation method

II.I. Park conversion

In SVM modulation method, 6-key 3-phase inverter is controlled between 8 unique states. This modulation technic is performed with switching between various states of inverter. For this purpose, Park conversion is required. Park conversion or dqo is a mathematical conversion that is applied to simplify three-phase circuit analysis. In case of balanced three-phase circuit, use of dqo conversion would reduce three alternating quantities to two quantities. The simplified calculations can be done for dummy quantities then obtain results of three-phase AC using reverse conversion. This conversion has been commonly used to simplify analysis of synchronous three-phase machines or to simplify calculations of inverter control. Figure 1 illustrates first step of Park conversion.

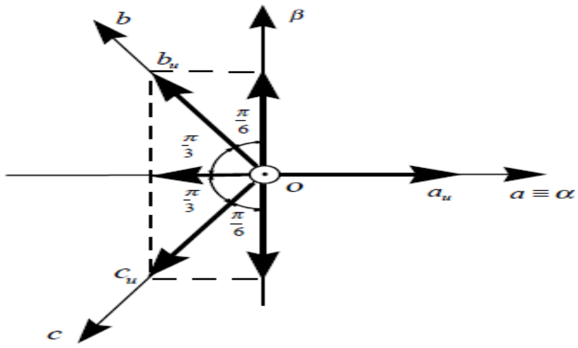


Fig 1. First step of Park conversion

a_u, b_u, and c_u are unit vectors. Unit vectors in line with axes a, b, c are converted to unit vectors in line with α and β. The observed trend in figure (1) has been formulated in equation (1).

$$\begin{aligned} \alpha_u &= k_d\left[a_u - sin\left(\frac{\pi}{6}\right)b_u - sin\left(\frac{\pi}{6}\right).c_u\right] \quad \Rightarrow \alpha_u = \left[a_u - \frac{1}{2}b_u - \frac{1}{2}c_u\right] \\ \beta_u &= k_q\left[0 + cos\left(\frac{\pi}{6}\right)b_u - cos\left(\frac{\pi}{6}\right).c_u\right] \quad \Rightarrow \beta_u = \left[0 + \frac{\sqrt{3}}{2}b_u - \frac{\sqrt{3}}{2}c_u\right] \end{aligned} \tag{1}$$

In equation (1), the size of unit vectors of α_u and β_u will be equal to 1 if values of coefficients K_d and K_q be equal to $\sqrt{2/3}$. According to the mentioned points, the equation (2) will be obtained if three-phase voltage vectors of V_a, V_b, and V_c are converted to vectors V_α and V_β.

$$\begin{bmatrix} V_\alpha \\ V_\beta \\ V_0 \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} 1 & \cos\left(\frac{2\pi}{3}\right) & \cos\left(\frac{2\pi}{3}\right) \\ 0 & \sin\left(\frac{2\pi}{3}\right) & -\sin\left(\frac{2\pi}{3}\right) \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix}\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix}\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \tag{2}$$

Now, constant coordinates (static αβ) are converted to rotating coordinates of d-q. This subject is illustrated in figure 2.

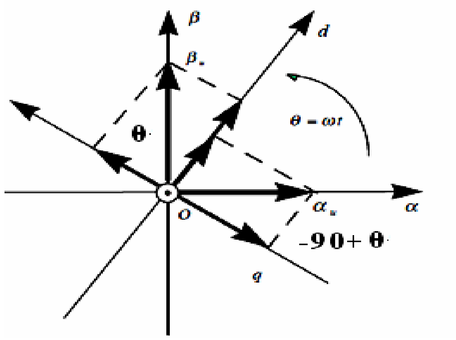


Fig 2. Converting static coordinates of αβ to rotating coordinates of dq

In general, equation (3) can be expressed for voltage and current.

$$I_{dq0} = P \cdot I_{abc} \qquad I_{dq0} = \begin{bmatrix} I_d \\ I_q \\ I_0 \end{bmatrix} \qquad I_{abc} = \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

$$V_{dq0} = P \cdot V_{abc} \qquad V_{dq0} = \begin{bmatrix} V_d \\ V_q \\ V_0 \end{bmatrix} \qquad V_{abc} = \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \tag{3}$$

Final Park matrix has been indicated in equation (4) along with reverse matrix.

$$P = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos(\theta) & \cos\left(\theta - \frac{2\pi}{3}\right) & \cos\left(\theta + \frac{2\pi}{3}\right) \\ \sin(\theta) & \sin\left(\theta - \frac{2\pi}{3}\right) & \sin\left(\theta + \frac{2\pi}{3}\right) \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \qquad P^{-1} = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos(\theta) & \sin(\theta) & \frac{1}{\sqrt{2}} \\ \cos\left(\theta - \frac{2\pi}{3}\right) & \sin\left(\theta - \frac{2\pi}{3}\right) & \frac{1}{\sqrt{2}} \\ \cos\left(\theta + \frac{2\pi}{3}\right) & \sin\left(\theta + \frac{2\pi}{3}\right) & \frac{1}{\sqrt{2}} \end{bmatrix} \tag{4}$$

In this case, conversion matrix is a function of angle θ; so it is not constant. It is possible to select rotation speed of axis q optionally (synchronous, asynchronous or non-zero). In Clark's conversion, if components of three-phase system of abc area function of time, components of αβ system will also be a function of time after converting; in contrary, it is possible in Park conversion components of dq have constant values by selecting a suitable rotation speed for dq axis. This has been illustrated in figure 3.

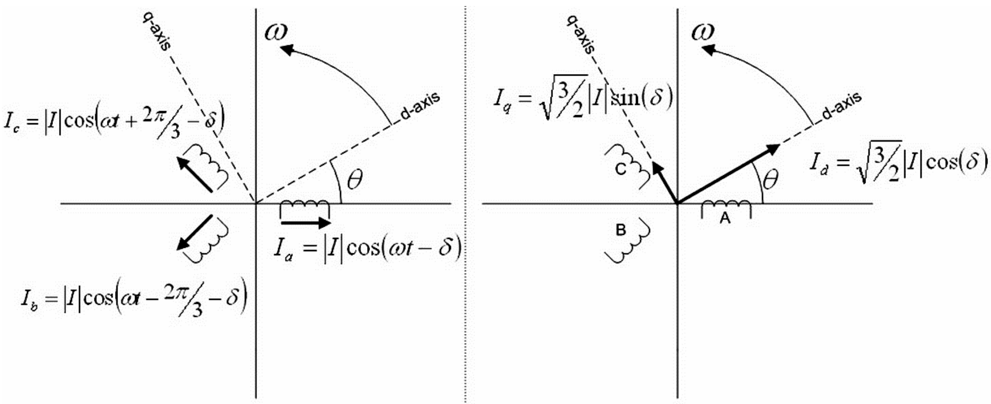


Fig 3. Overview of Park conversion

Considering the conversion process from balanced three-phase constant system to balanced rotating system of dq, equations I_d and I_q are rewritten and illustrated in equation (5). In equation (5), if we want the peak values of I_d and I_q at sinusoidal current to be one, we should select K_d=K_q=2/3. Replacing equations of three-phase currents (I_a, I_b, I_c) in equation (5), it is possible to find the reason for this selection change for coefficients K_d and K_q. After simplifying the equation (5), the result is indicated in equation (6).

$$
\begin{aligned}
I_d &= K_d\left[I_a\cos(\theta)+I_b\cos\left(\theta-\frac{2\pi}{3}\right)+I_c\cos\left(\theta+\frac{2\pi}{3}\right)\right]\\
I_q &= K_q\left[I_a\sin(\theta)+I_b\sin\left(\theta-\frac{2\pi}{3}\right)+I_c\sin\left(\theta+\frac{2\pi}{3}\right)\right]
\end{aligned}
\tag{5}
$$

$$
\begin{aligned}
I_d &= K_d\,\frac{3}{2}\left[I_m\sin(\omega t-\theta)\right]\\
I_q &= K_q\,\frac{3}{2}\left[I_m\cos(\omega t-\theta)\right]
\end{aligned}
\tag{6}
$$

The zero component's current is obtained from equation (7) using modified Park matrix.

$$
\begin{bmatrix} I_d \\ I_q \\ I_0 \end{bmatrix} = \frac{2}{3}
\begin{bmatrix}
\cos(\theta) & \cos\left(\theta-\frac{2\pi}{3}\right) & \cos\left(\theta+\frac{2\pi}{3}\right)\\
\sin(\theta) & \sin\left(\theta-\frac{2\pi}{3}\right) & \sin\left(\theta+\frac{2\pi}{3}\right)\\
\frac{1}{2} & \frac{1}{2} & \frac{1}{2}
\end{bmatrix}
\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}
\tag{7}
$$

$$
I_0 = \frac{1}{3}\left[I_a+I_b+I_c\right]
$$

The first step in implementing and simulating SVM method is conversion of static balanced three-phase system to balanced rotating dq system. This action has been done using modified Park matrix in this section.

II.II. Three-Wire Three-Phase Inverter (6-Switch)

Figure 4 indicates the structure of three-wire three-phase inverter that is called 6-switch three-phase inverter. Figure 5 shows the size of three-phase vectors and their total amounts in vector space (pre-unit). There are 8 switching modes in space vector modulation for the structure indicating in figure 4. All of these 8 modes are shown in figure 6.

Since there are 8 modes for switching and generating vectors V_0-V_7, all of modes should be analyzed separately to obtain values V_{an}, V_{bn}, V_{cn}. For instance, in first mode that is pnn connection mode- or connection (100), values V_{an}, V_{bn}, V_{cn} are obtained from equation 8. For this purpose, consider the equivalent electric circuit of 5-switch three-phase inverter indicating in figure 6.

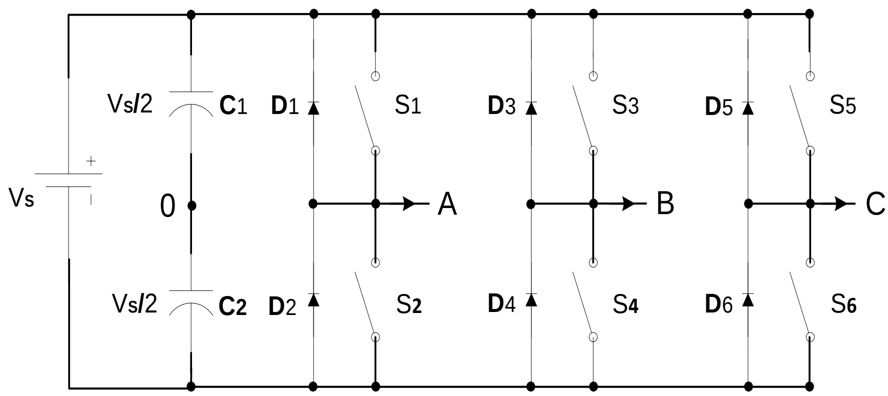


Fig 4. Structure of three-wire three-phase inverter

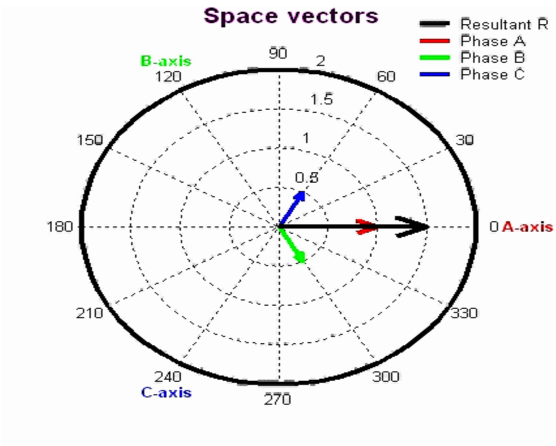


Fig 5. Structure of three-wire three-phase inverter

$$R_{eq} = R + \frac{R}{2} = \frac{3R}{2}$$
$$V_{an} = R \times i_{an} = R \times \frac{Vs}{R_{eq}} = \frac{2V_S}{3} \qquad V_{bn} = V_{cn} = -\frac{V_S}{3} \tag{8}$$

Similar to first mode, equivalent electric circuits for all other modes should be investigated to obtain values V_{an}, V_{bn}, V_{cn} for all of modes. Results this investigation have been summarized in table 1.

Table 1. Switching Modes of Voltage Reference Inverter In SVM Technic

Mode	On switches	V_{an}	V_{bn}	V_{cn}	Voltage space vector
0	S2, S4, S6	0	0	0	V0 (000)
1	S1, S4, S6	2Vs/3	-Vs/3	-Vs/3	V1 (100)
2	S1, S3, S6	Vs/3	Vs/3	-2Vs/3	V2 (110)
3	S2, S3, S6	-Vs/3	2Vs/3	-Vs/3	V3 (010)
4	S2, S3, S5	-2Vs/3	Vs/3	Vs/3	V4 (011)
5	S2, S4, S5	-Vs/3	-Vs/3	2Vs/3	V5 (001)
6	S1, S4, S5	Vs/3	-2Vs/3	Vs/3	V6 (101)
7	S1, S3, S5	0	0	0	V7 (111)

Figure 6 circuit mode and vector analysis related to vector V_1.

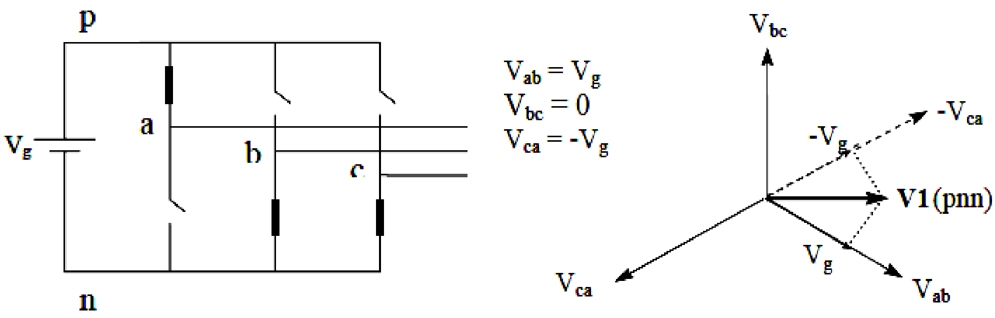


Fig 6. A) Circuit mode of connection (100), B) vector analysis of mode (100) with line voltage vectors

To obtain size of vector V_1, this vector is imaged on V_{ab} , using sirsuit 6-A.

$$V_1 \cdot cos(30) = V_g \qquad \Rightarrow |V_1| = \frac{2}{\sqrt{3}} V_g \tag{9}$$

In this regard, 6 other non-zero vectors (V_1-V_6) are obtained as it is seen in figure 7. These 6 vectors form a regular hexagonal. The number of each region between two vectors is depicted in figure 7. To implement SVM method, steps are classified to three parts as follows:

1- Determining V_d, V_q, V_{ref} and α (the angle between reference vector (V_{ref}) and closest non-zero vector to it)
2- Determining times T_0, T_1, and T_2 for one zero mode vector and two non-zero vectors
3- Determining switching time of each transistor (a, b, c)

According to figure 8, the first step has been summarized in equation 10.

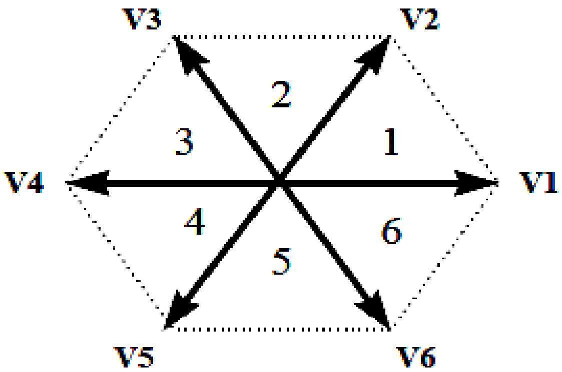


Fig 7 non-zero voltage vectors on page dq

Stage 1

$$V_d = V_{an} - V_{bn}\cdot\cos(60) - V_{cn}\cdot\cos(60) = V_{an} - \frac{1}{2}V_{bn} - \frac{1}{2}V_{cn} \qquad V_q = 0 + V_{bn}\cdot\cos(30) - V_{cn}\cdot\cos(30) = 0 + \frac{\sqrt{3}}{2}V_{bn} - \frac{\sqrt{3}}{2}V_{cn}$$

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} \Rightarrow \begin{cases} \left|\overline{V_{ref}}\right| = \sqrt{V_d^2 + V_q^2} \\ \alpha = \tan^{-1}\left(\frac{V_q}{V_d}\right) = \omega t = 2\pi f \end{cases} \qquad (10)$$

In equation 10, f is the frequency of main component. In figure 9, $d_1 = T_1/T_S$ and $d_2 = T_2/T_S$. Vector length on the axis V_1 is equal to $(T_1/T_S)V_1$ and Vector length on the axis V_2 is equal to $(T_2/T_S)V_2$. According to figure 9 and mentioned points, second step is summarized in equation 11.

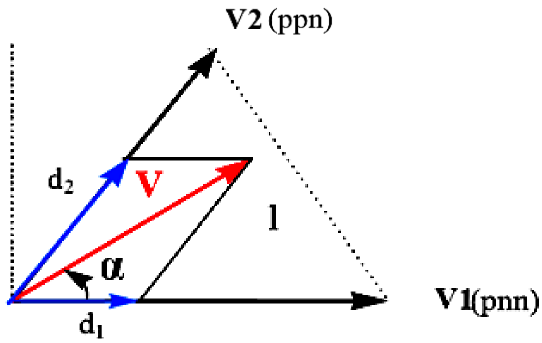


Fig 9. Times T1, T2, and T0 at second step

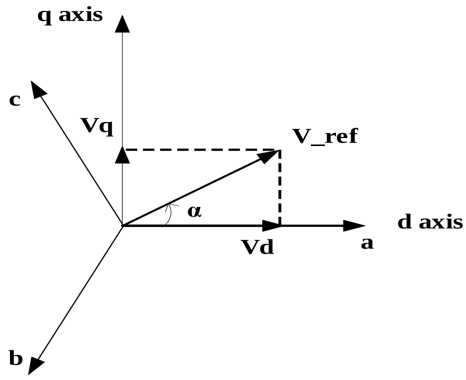


Fig 8. Conceptual relation between reference voltage vector and its angle with axis d

In equation 11, n indicates the number of sectors of regular hexagonal shown in figure 7. As it was explained before, the time in which, transistors of inverter circuit (S_1-S_6) should be on in phases a, b, and c needs to be determined. There are various patterns for switching methods, among them, symmetric switching pattern has been selected for this study. Symmetric switching pattern is shown in figure 10.

$$step\,2 \qquad\qquad V = V_{ref}$$

$$\begin{aligned}
&V \cdot T_S = V_1 \cdot T_1 + V_2 \cdot T_2 + V_0 \cdot \left(\frac{T_0}{2}\right) + V_7 \cdot \left(\frac{T_0}{2}\right) \\
&T_1 = \frac{\sqrt{3} \cdot T_S \left|V_{ref}\right|}{V_S}\left(\sin\left(\frac{n}{3}\pi\right)\cos(\alpha) - \cos\left(\frac{n}{3}\pi\right)\sin(\alpha)\right) \\
&T_2 = \frac{\sqrt{3} \cdot T_S \left|V_{ref}\right|}{V_S}\left(-\cos(\alpha)\sin\left(\frac{n-1}{3}\pi\right) + \sin(\alpha)\cos\left(\frac{n-1}{3}\pi\right)\right) \\
&T_0 = T_S - T_1 - T_2 \qquad\qquad n = 1, 2, \ldots, 6
\end{aligned} \tag{11}$$

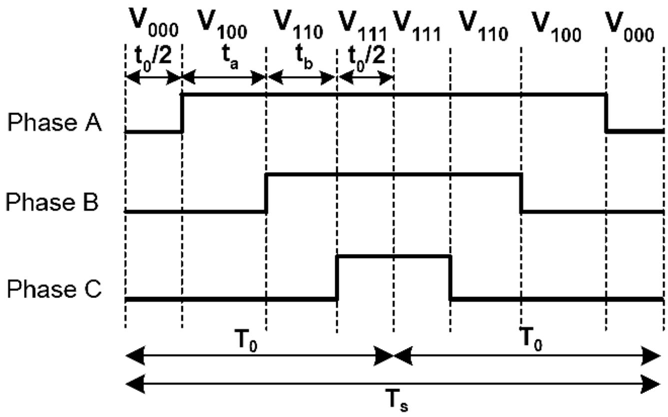
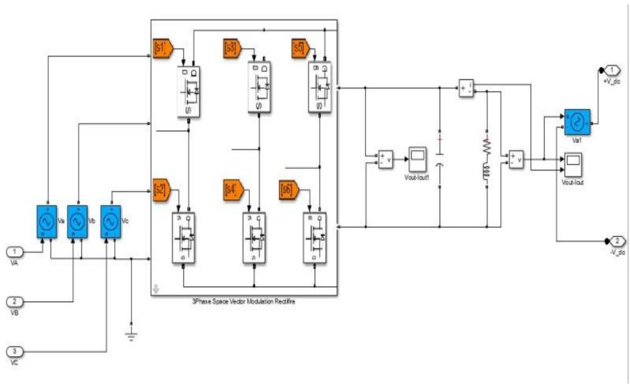


Fig 10. Symmetric switching pattern in SVM method

III. Simulation results

In this research, simulation was carried out using Simulink of MATLAB Software under non-sinusoidal input. A general schema of simulation of inverter sector of space vector modulation in matrix converter is shown in figure 11. Figure 12 also shows a general schema of simulation of virtual rectifier sector of SVM in matrix converter. In addition, figure 13 indicates a schema of simulation of reference vector and displacement angle in SVM.

At the first stages of simulation, the switching angles presented in table 1 were applied as switching signals from S1 to S6 in inverter sector of indirect matrix converter indicated in figure 13.



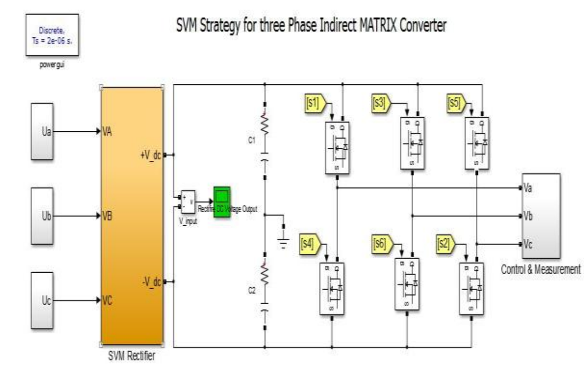


Fig 12. General schema of virtual rectifier sector of 2matrix converter

Fig 11. General schema of simulation of indirect matrix converter

According to results and comparing them with modified space vector modulation technic that was presented in reference [7], the generation trend of switching signals presented in this paper is seen in figure 14. The general schema of simulation of switching in inverter sector of space vector modulation in matrix converter has been shown in figure 14.

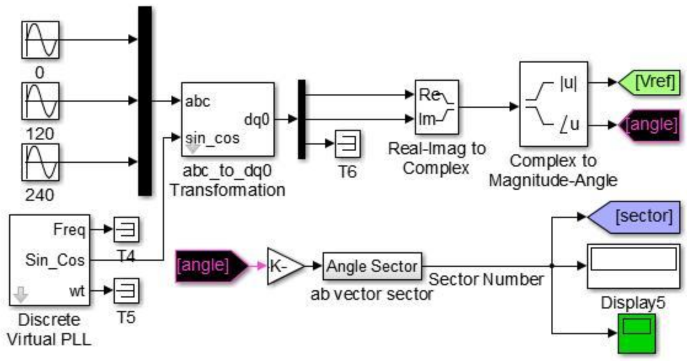


Fig 13. Generation of reference voltage vector along with its displacement angle

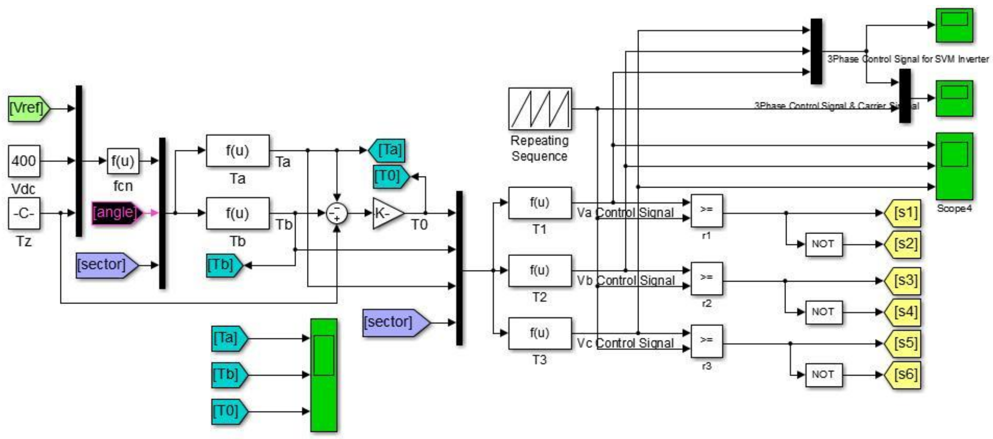
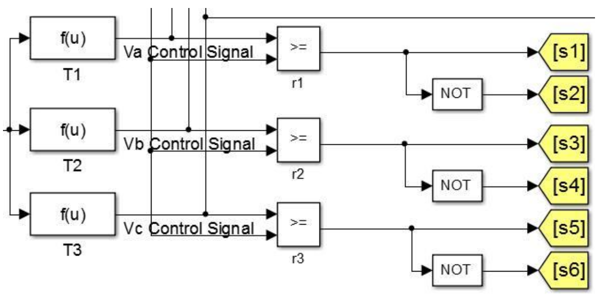


Fig 14. Generating switching signals of inverter sector of indirect matrix converter

According to the initial results obtained from simulation steps and comparing them with reference case and other articles, values T_a, T_b, T_0, T_1, T_2, T_3 in figure 14 are optimal a better schema of the method used to obtain values T_a, T_b, T_0, T_1, T_2, T_3 and their relationships can be seen in figures 15 and 16.



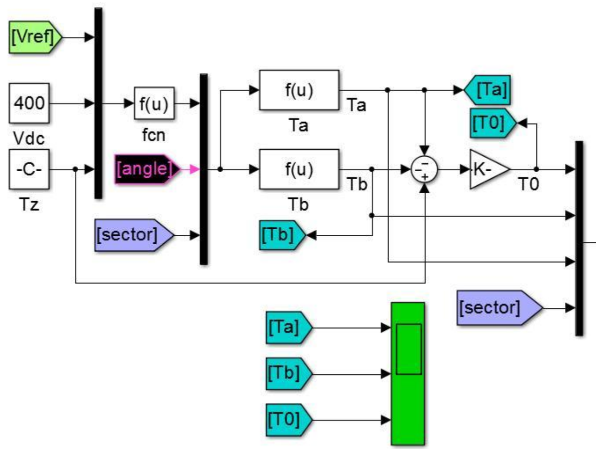


Fig 16. Extracting switching signals S1-S6 using times T_1, T_2, T_3

Fig 15. Applying mathematical operations to generate times T_0, T_1, T_2

As it is shown in figure 16, switching signals S_1-S_6 extracted by using T_1, T_2 and T_3 which are shown in equations (12) to (17). The form of applied input wave has been illustrated in figure 17.

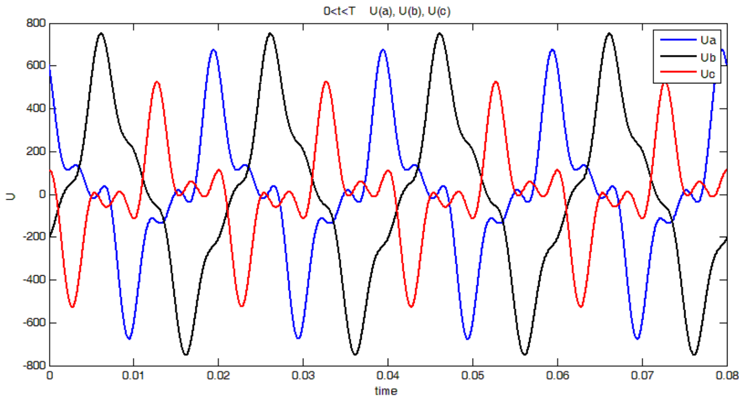


Fig 17. Input wave of indirect matrix converter

$$Fcn = \frac{\sqrt{3} \times T_S \times \left|V_{ref}\right|}{V_{dc}} \tag{12}$$

$$T_a = Fcn \times \left[\sin\left(N \times \frac{\pi}{3}\right).\cos(\alpha) - \cos\left(N \times \frac{\pi}{3}\right).\sin(\alpha) \right]$$

$$T_b = Fcn \times \left[\cos\left((N-1) \times \frac{\pi}{3}\right).\sin(\alpha) - \sin\left((N-1) \times \frac{\pi}{3}\right).\cos(\alpha) \right] \tag{13}$$

$$T_0 = \frac{1}{2}(T_S - T_a - T_b) \tag{14}$$

$$\begin{aligned} T_1 = &(N=1)\times(T_0+T_b+T_a)+(N=6)\times(T_0+T_b+T_a)+(N=2)\times(T_0+T_a)+ \\ &+(N=3)\times(T_0)+(N=4)\times(T_0)+(N=5)\times(T_0+T_b) \end{aligned} \tag{15}$$

$$\begin{aligned} T_2 = &(N=6)\times(T_0)+(N=1)\times(T_0+T_b)+(N=2)\times(T_0+T_b+T_a)+ \\ &+(N=3)\times(T_0+T_b+T_a)+(N=4)\times(T_0+T_a)+(N=5)\times(T_0) \end{aligned} \tag{16}$$

$$\begin{aligned} T_3 = &(N=6)\times(T_0+T_a)+(N=1)\times(T_0)+(N=2)\times(T_0)+ \\ &+(N=3)\times(T_0+T_b)+(N=4)\times(T_0+T_b+T_a)+(N=5)\times(T_0+T_b+T_a) \end{aligned} \tag{17}$$

As it is seen in figure 17, the form of input wave contains numerous harmonic values making it out of the balance mode; however, the objective of this study was to convert any kind of alternating unbalanced waveform to a sinusoidal waveform with a suitable quality. Harmonic spectrum of input three-phase voltage is illustrated for each phase in figures 18-20.

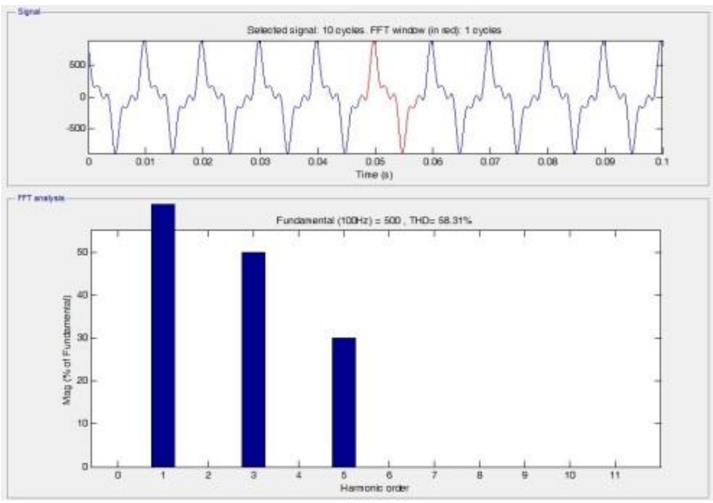


Fig 18. Harmonic spectrum of input voltage of matrix converter for phase A

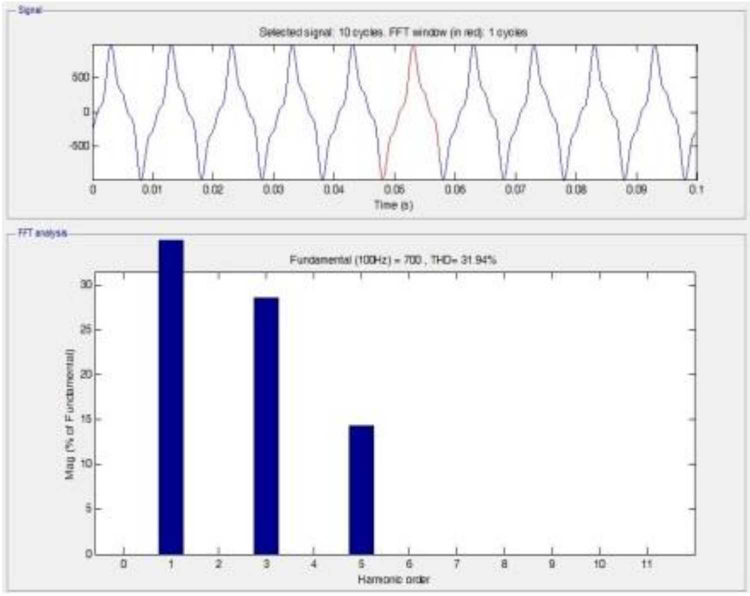


Fig 19. Harmonic spectrum of input voltage of matrix converter for phase B

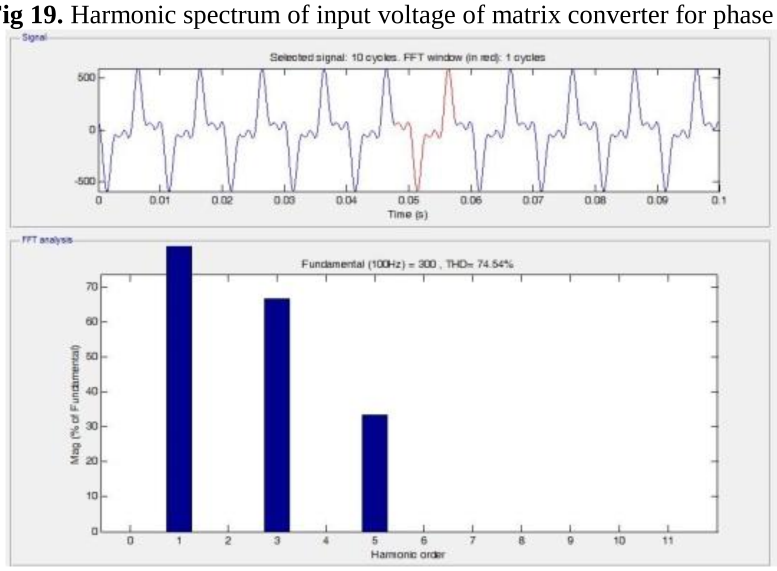


Fig 20. Harmonic spectrum of input voltage of matrix converter for phase C

As can be seen, total harmonic values of input voltage to matrix converter in phases A, B, C are 58.31%, 31.94% and 74.54%, respectively indicating unbalanced and non-sinusoidal values. The waveform of virtual rectifier output of indirect matrix converter has been illustrated in figure 21.

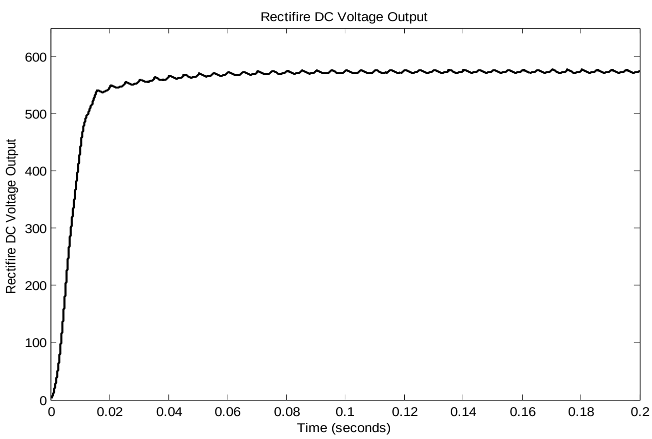


Fig 21. Waveform of rectifier output voltage

The waveform obtained from changes in 6 sectors of SVM method in matrix converter has been presented in figure 22. Figure 23 depicts waveform of control signal of inverter sector in space vector modulation.

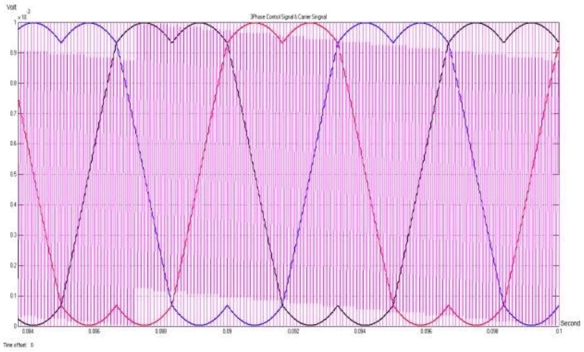


Fig 23. Waveform of inverter control signal along with carrier wave

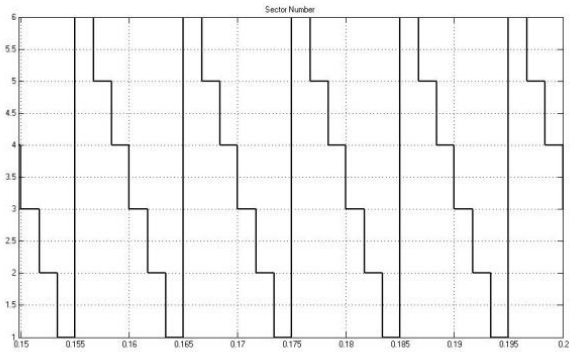


Fig 22. 6 vector sectors in SVM

Figure 24 indicates waveform of output line voltage of virtual inverter in indirect matrix converter. Harmonic spectrum of output line's voltage waveform of virtual inverter sector in matrix converter has been illustrated in figure 25. As it's shown in Fig. 25 the amount of line voltage THD was reached to 0.16 percent.

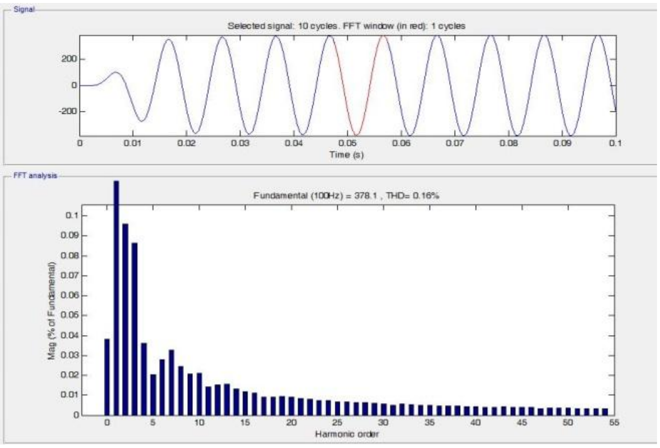


Fig 25. Harmonic spectrum of output line's voltage waveform of virtual inverter sector in matrix converter

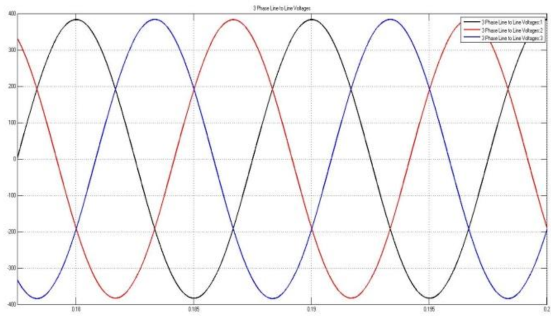


Fig 24. Waveform of output line voltage of virtual inverter sector in indirect matrix converter

Figure 26 indicates waveform of output Phase voltage of virtual inverter sector in indirect matrix converter. Harmonic spectrum of waveform of output phase voltage in virtual inverter sector of matrix converter has been illustrated in figure 27. As it's shown in Fig. 27 the amount of phase voltage THD was reached to 0.17 percent.

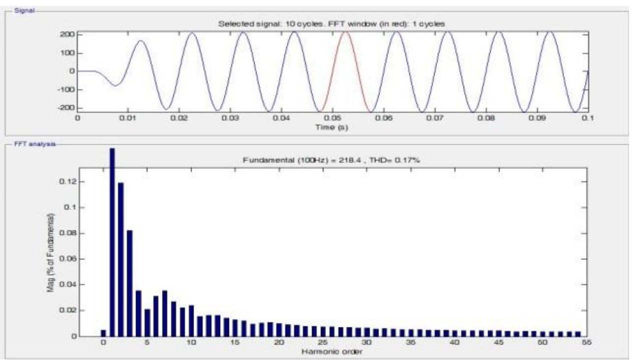


Fig 27. Harmonic spectrum of waveform of output phase voltage in virtual inverter sector of matrix converter

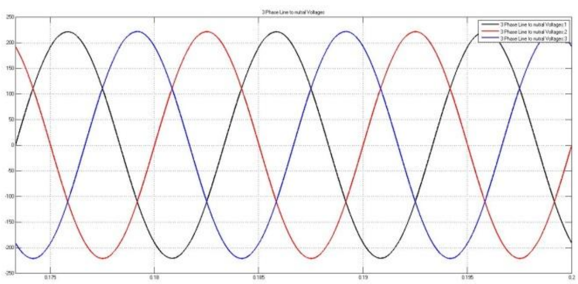


Fig 26. Waveform of output Phase voltage of virtual inverter sector in indirect matrix converter

Compared to reference case [7] in which, harmonic distortion amount of total phase voltage is 0.86 using same input, the present paper indicate a considerable reduction in total harmonic disturbance value equal to 0.17 which indicate the superiority of suggested method in comparison with modified method in reference [7]. Figure 28 indicates waveform of three-phase output of matrix converter along with harmonic spectrum in reference case. It should be noted that for comparison between reference case and present paper the waveform illustrated in figure 17 has been imposed as unbalanced and non-sinusoidal input voltage to the indirect matrix converter for both cases.

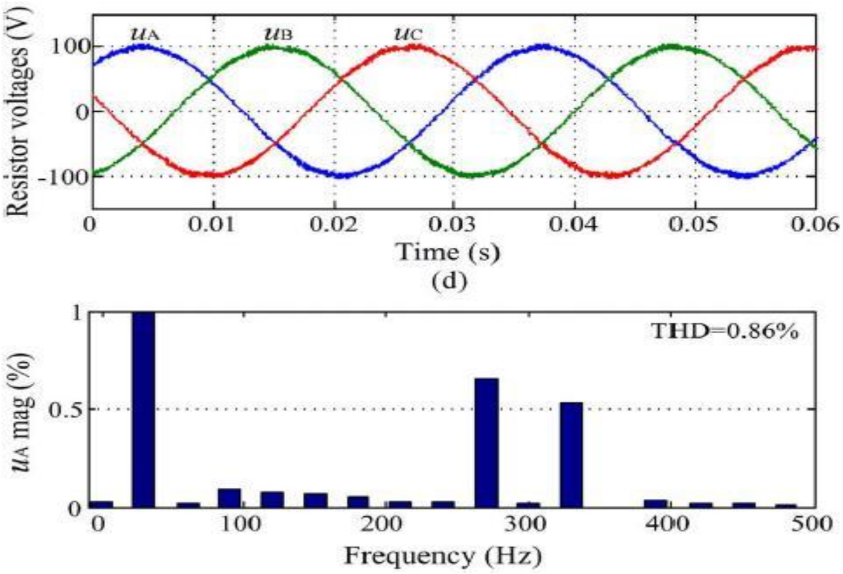


Fig 28. Waveform of three-phase output of matrix converter along with its harmonic spectrum

IV. Conclusion

This study was conducted to examine the structure and performance of matrix converter and its position compared to other AC converters. Due to lack of capacitor in these converters, the volume of them has been reduced compared to previous converters. Matrix converters have rapid response, high efficiency, small size, and integrated design. Two modulation methods of second-generation space vector modulation and Venturini SVM were mentioned for the matrix converters control; in Venturini SVM method, maximum output voltage was obtained adding third harmonic of output and input voltages to output voltage, while self-modulation voltage line in second-generation SVM method makes it possible to achieve such output voltage level. It was determined that computational steps in second-generation SVM method are simpler than Venturini SVM method, because calculations of sinusoidal functions are lesser in second-generation SVM method. Total input current is lower in a converter that is controlled using second-generation SVM method compared to the converter that is controlled by Venturini SVM method. Moreover, a modified SVM strategy was presented for matrix converter under abnormal conditions. In this strategy, instantaneous size of vector of output and input voltages was used to calculate voltage modulation index and input current phase angle. Therefore, functioning periods of switching modes are calculated considering input voltage disturbances. Output voltages can be determined under normal and abnormal input voltage conditions using this strategy and fixing reference voltages. Validity of theoretical analyses and efficiency of modulation strategy has been verified by simulation. Ultimately, in the suggested SVM method in this research, switching duration of inverter sector of matrix converter became dependent on sector number in which base voltage exits at the time of switching and a considerable improvement was observed in results compared to modified method suggested by reference case [7].

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