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Performance Analysis of Very Sparse Matrix Converter Using Indirect Space Vector Modulation

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Abstract: In this p aper, Matrix Converter is which converts the AC to AC in a single stage. The merits of the matrix converter is its able to deliver variable output voltage with unrestricted input and output frequency, the lack of electrolytic capacitors, and the potential to raise the power density, decrease the size, less weight and better input power quality. In whatever way, application of these converters are restricted because of some issues such as different control strategies, high susceptibility to input power disturbances, common mode voltage effects and less voltage transfer ratio. Recently, matrix converters have gained a resurgence of importance due to the improvements in the semiconductor device industry and the increasing of processor technologies, which promises real implementation of matrix converters in the control of drives. The real effect of indirect space vector modulation scheme for very sparse matrix converter performance will be measures by testing of computationally for using indirect space vector modulation strategies with the passive R load and active load .

Keywords: indirect space vector modulation (ISVM), Matrix converter, Total Harmonics Distortion (THD)

I. INTRODUCTION

Matrix converters are which do not hold a direct link circuit with passive components, like conventional frequency converters. Thus, matrix converters may supply a solution for applications where large passive components are not allowed, or a purely semiconductor-based solution provides an economically more efficient result than conventional frequency converters. However, the lack of a link circuit may also be a drawback in non-ideal operation conditions and the linear structure also places restrictions on converter capability. MCs is that it supplies a compact solution for a four-quadrant converter delivering sinusoidal input and output without passive components in DC link. (1) The Indirect Matrix Converter (IMC) offers the same benefits and disadvantages as the Direct Matrix Converter (DMC), but it likewise provides an option to lower the switch count of the line bridge to three if no bidirectional power flow is required. Safe commutation of semiconductor devices produces smooth variation in converter output voltage. The matrix converter has separate circumstances over usual rectifier-inverter type frequency power converters. The matrix converter makes sinusoidal input and output waveforms, it requires small amount number of energy storage components, which allows getting rid of much space and lifetime- limited energy-storing capacitors.However, Many components are required for power frequency conversion compared with conventional indirect power frequency converters system.The research in matrix converter leading to an advancd technology and application such as the reliable enhancement of the modified topologies, operation under abnormal conditions and the design. The sparse matrix converters were classified as (i) Simple Sparse Matrix Converter (SSMC) with 15 switches, (ii) Very Sparse Matrix Converter (VSMC) with 12 switches and (iii) Ultra Sparse Matrix Converter (USMC) with nine switches (3). The VSMC and the USMC were designed based on the fact that the DC link current only flows in one direction. This constraint makes the VSMC and the USMC not applicable for regenerative operation. (4) Nine switches only effective methods in matrix converter in the vector control of an induction motor with high-quality input and output currents. the effectiveness of the new SVPWM modulation strategy in modifing voltage transfer ratio and reduce the switching losses. Compared with the conventional space vector modulation strategy, the new type of reconfigurable matrix converter SVPWM strategy has the advantages. In (2) a drive open-ended winding AC machines with topology based of indirect matrix converter have been presented. In input rectifier two modulation strategies have been used, it will depends how much output voltage needed. One modulation strategy aims for a maximum positive DC voltage.

II. MATRIX CONVERTER TOPOLOGY

The Matrix Converter (MC) consists of nine bi-directional switches that permits any output phase to be connected to any phase of input. Figure 2.1 depicts the circuit system. The input line of the converter are connected to a three-phase voltage system, while the output end is interconnected to a three-phase load system. Capacitive and inductive filters are provided on the voltage fed side and current fed side of the converter respectively as shown in Figure 2.1.

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The size of the filtering components is inversely proportional to the matrix converter switching frequency. It is worth noting that due to its inherent bi-directionality and symmetry a dual connection might also be feasible for the matrix converter: a current- fed system at the input and a voltage- fed system at the output.

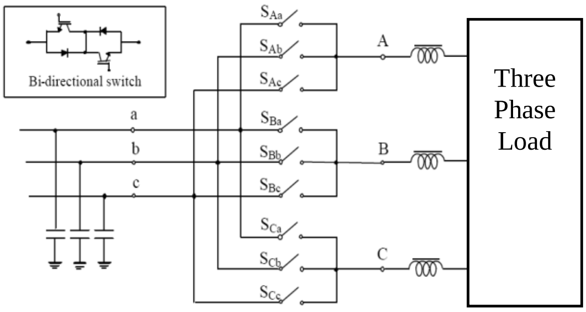


Fig .1. Circuit diagram of a 3 phase to 3 phase matrix converter

The matrix converter can theoretically assume 512 different switching states combinations with nine bi-directional switches. No matter of the control method used, the selection of the matrix converter switching state combinations used to follow with two fundamental patterns. A voltage source supplies the converter and usually feed to an inductive load; the input phases should not short-circuit, and the output currents should not be disturbed. From a practical point of view, only one bi-directional switch should be switched on per phase at any instant. By using this conditiont, the matrix converter topology allowed 27 switching combinations.

2.1 DIRECT MATRIX CONVERTER TOPOLOGY

The direct matrix converter topology provides of n * p bi-directional switches, linking the n-input line to the p-output line to provide a undeviting power conversion Alesina & Venturini (1989), Alesina & Venturini (1988), Wheeler et al. (2001), Venturini (1980). The converter is designed by its ability to link any input phase to any output phase at desired instant. An input phase of n-line and output phase p-line direct matrix converter topology is shown in Figure 2 features of direct matrix converter topology

- Having the form of sine curve input current and output voltage
- It allows bi-directional switches, which activates regenerating energy back to the source.
- It can modify the input power factor of the converter inspite of the type of the load connected..
- Since DC link energy storage is not present in this converter. Since the size and cost of the converter are reduced.

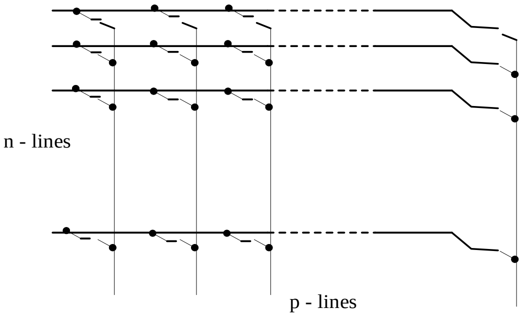


Fig.2 MC topology of n-input line to p-output line

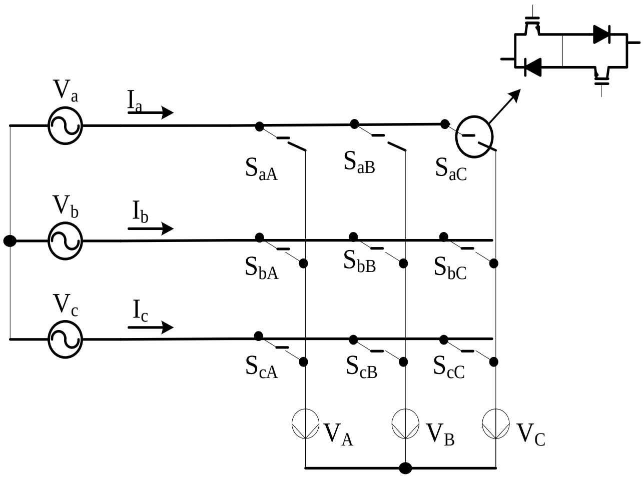


Fig.3. A 3-phase to 3-phase AC-AC matrix converter

A 3-phase-to-3-phase AC-AC matrix converter topology consists of 9 bi-directional switches connected in such a way that any of the input phases is connected to any of the output phases of the converter as shown in Fig 3. The bi-directional switches allow the process of current in both directions and block voltage of both polarities. Presently The direct matrix converter topology is not suitable for use in industries , because of the difficulty in the control and commutation failure.

2.2 INDIRECT MATRIX CONVERTER TOPOLOGY

The complexity of its conventional PWM control strategy and the commutation problem eliminated from industry. This proposed approach is used to overcome these failures . Neft & Schauder (1992), Kolar et al. (2002), Klumpner & Blaaberg (2002). It is a two-stage converter topology known as an indirect matrix converter. This topology is identical to the conventional inverter-based topology without any reactive DC-link energy storage components for the intermediate imaginary DC-link bus. A block diagram of the indirect matrix converter topology is shown in Fig.3

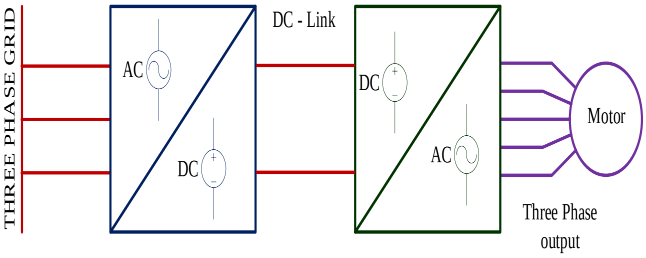


Fig.4. Indirect matrix converter topology block diagram

the desired merits of the direct matrix converter topology, such as sinusoidal input current and output voltage, four-quadrant operation, unity power factor, no DC-storage elements are achieved by this indirect matrix converter topology. Also, this topology reduce the complexity of the conventional PWM control strategy and dealing the commutation problems of the previous topology. A rectifier stage to provide an imaginary DC-link during the switching cycle and an inverter stage to generate the three-phase desired output voltages.

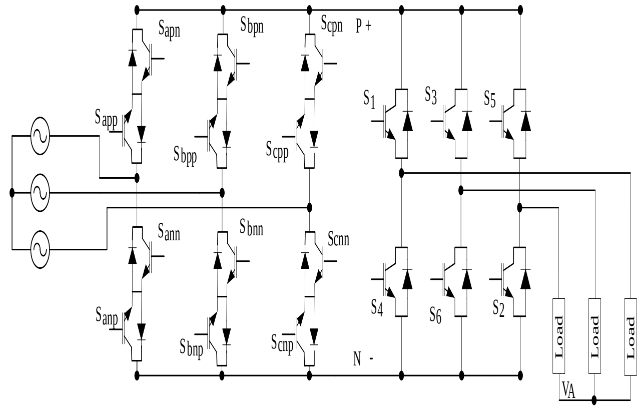


Fig.5. Indirect matrix converter topology

2.3 Circuit Topology and Operating Principle of VSMC

The Very Sparse Matrix Converter Topology consist of tweleve Transistors and thirty Diodes. When compared to the Sparse Matrix Converter it uses a least number of transistors but the conduction losses increasesd due to more diodes in the conduction paths. Figure 2.5 shows the circuit diagram of Very Sparse Matrix Converter.by the use of diode bridge configuration circuit with bidirectional switching cell the rectifier section with inverter section remains same. Six diode bridge bidirectional switching (DBBS) cell are used in this scheme.

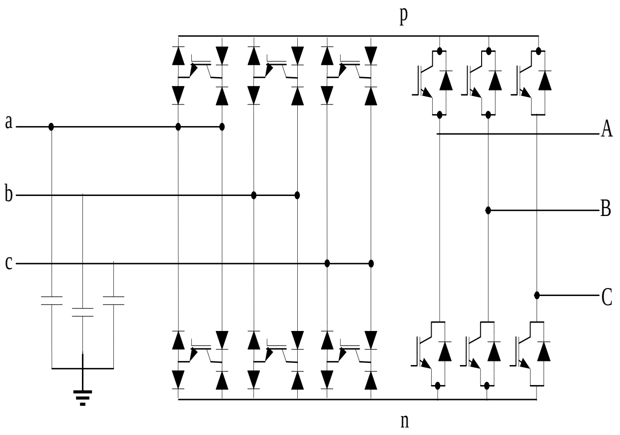


Fig.6. Very Sparse Matrix Converter

III INDIRECT SPACE VECTOR MODULATION (ISVM)

The matrix converter as an combination of a virtual input rectifier and a virtual output inverter, linked by a virtual DC-link Ziogas et al. 1986. MC is controlled (modulated) by connecting an appropriate set of switching functions in such a way that the desired output voltages and input currents are achieved. Many methods have been reported Huber & Borojevic (1995), Casadei et al. (2002), Wheeler et al. (2002). This paper focuses on space vector methods, particularly on the indirect space vector modulation method. which is almost similar to the back to back converter, but without a DC li.nk. Equation 4.4 . space vector modulation can be applied to the rectifier and inverter stages of an circuit, to achive the switching functions to be evaluated to the different topologies of IMC.

$$\begin{bmatrix} S_{Aa} & S_{Ab} & S_{Ac} \\ S_{Ba} & S_{Bb} & S_{Bc} \\ S_{Ca} & S_{Cb} & S_{Cc} \end{bmatrix}^t = \begin{bmatrix} S_{apn} & S_{ann} \\ S_{bpn} & S_{bnn} \\ S_{cpn} & S_{cnn} \end{bmatrix} . \begin{bmatrix} S_{app} & S_{bpp} & S_{cpp} \\ S_{anp} & S_{bnp} & S_{cnp} \end{bmatrix}$$

$$= \begin{bmatrix} S_{apn}.S_{app} + S_{ann}.S_{anp} & S_{apn}.S_{bpp} + S_{ann}.S_{bnp} & S_{apn}.S_{cpp} + S_{ann}.S_{cnp} \\ S_{bnp}.S_{app} + S_{bnn}.S_{anp} & S_{bnp}.S_{bpp} + S_{bnn}.S_{bnp} & S_{bnp}.S_{cpp} + S_{bnn}.S_{cnp} \\ S_{cpn}.S_{app} + S_{cnn}.S_{anp} & S_{cpn}.S_{bpp} + S_{cnn}.S_{bnp} & S_{cpn}.S_{cpp} + S_{cnn}.S_{cnp} \end{bmatrix}$$

The reference vectors, v_o and i_i, are situated in S_{inv} and S_{rect} sectors in respectively. So 6x6=36 possible combinations exist.

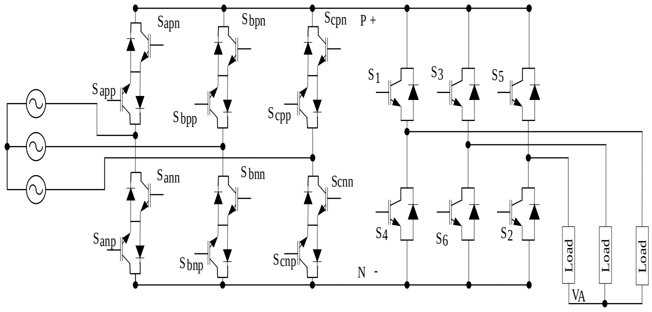
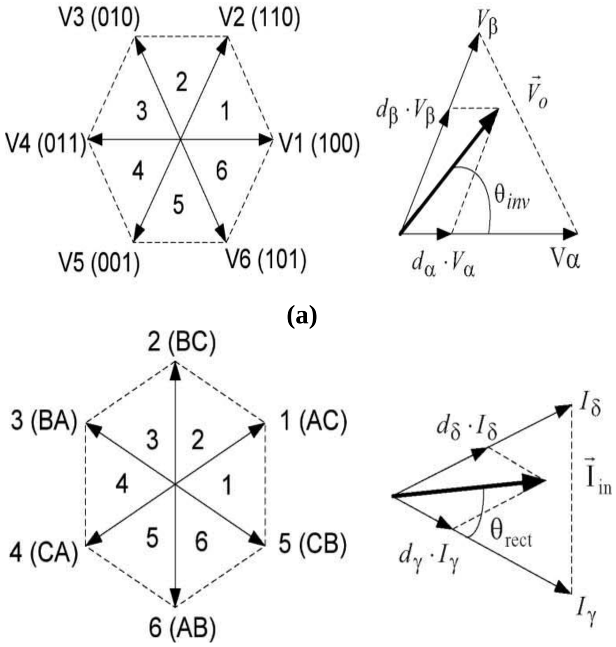


Fig.7. Matrix converter equivalent circuit



(a)

(b)

Fig.8. Six Switching Intervals based on the Line Side Voltage

Fig.8 illustrates the six switching sequence which are identified depending on the input voltage here is only one input voltage, which has the highest absolute value during every interval, out of the three input voltages. For example, V_a has the biggest absolute voltage in the interval V_b and I has the major absolute voltage in the interval III and so forth.

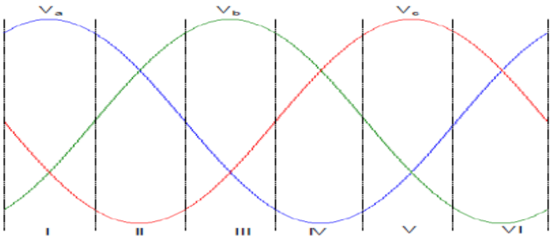


Fig.9. Six intervals based on the input synchronization angle

3.2 Converter Switching State and Determination of Duty Cycle

The switching cycle T_s is splited into two sections, where the switching state of the line side switch is stable, and the DC side voltage V_{pn} is equal to one of the two highest positive line voltages in each portion. Consider interval I, V_a has the largest absolute voltage, and the two biggest positive line voltages are

$V_{ab} = (V_a - V_b)$ and $V_{ac} = (V_a - V_c)$ respectively. The line side switching states in each portion is determined by the following:

- The portion I: Switches S_{app}, S_{apn}, S_{bnn}, and S_{bnp} are switched on, and the remaining of the line side switches are switched off. V_{pn} is equal to the line voltage V_{ab}, and the i_{pn} of the rectifier is equal to i_a and $-i_b$. The current i_c equals zero since the switches are becomes off. The duty cycle of this portion is defined as:

$$d_{ba} = \frac{-V_b}{V_a} = \frac{-\cos(\theta_b)}{\cos(\theta_a)} \qquad (3.2)$$

The fixed DC voltage V_{pn} during this first portion is given as:

$$V_{pn} = d_{ba} * V_{ab} = d_{ba} * (V_a - V_b) \qquad (3.3)$$

- Portion II: Switches S_{app}, S_{apn}, S_{cnn}, and S_{cnp} are switched on, and the remaining of the line side switches are switched off. voltage V_{pn} is then equal to the line voltage V_{ac}, and the i_{pn} of the rectifier is equal to i_a and $-i_c$. The current i_b equals zero since the switches are becomes off. The dutycycle of this is section defined as:

$$d_{ca} = \frac{-V_c}{V_a} = \frac{-\cos(\theta_c)}{\cos(\theta_a)} \qquad (3.4)$$

The fixed DC voltage V_{pn} during this next portion is given as:

$$V_{pn} = d_{ca} * V_{ac} = d_{ca} * (V_a - V_c) \qquad (3.5)$$

The fixed DC voltage V_{pn} provided by the rectifier converter stage for this particular switching period T_s is:

$$V_{pn} = d_{ba} * V_{ab} + d_{ca} * V_{ac}$$

$$V_{pn} = d_{ba} * (V_a - V_b) + d_{ca} * (V_a - V_c) \qquad (3.6)$$

where: $d_{ba} + d_{ca} = 1$.

Substituting two-stage converter Equation (3.1) and (3.2) in (3.4) will result in Equation (3.6):

$$\begin{pmatrix} V_A \\ V_B \\ V_C \end{pmatrix} = \begin{pmatrix} S_1 & S_4 \\ S_3 & S_6 \\ S_5 & S_2 \end{pmatrix} * \begin{pmatrix} V_p \\ V_n \end{pmatrix}$$

$$V_{pn} = \frac{3}{2 \cdot |\cos(\theta_a)|} V_{im} \qquad (3.7)$$

3.3 Simulink model of PWM and signal generation involving ISVM strategy

With less switching losses, symmetric switching strategy Larsen et al. (2002) is used to organize the five levels to be applied to the IMC during each period. The power circuit is fabricated using the Simulink Sim Power Systems toolbox, enabling a more clear structure of the whole model. Switching pulse of proposed ISVM .

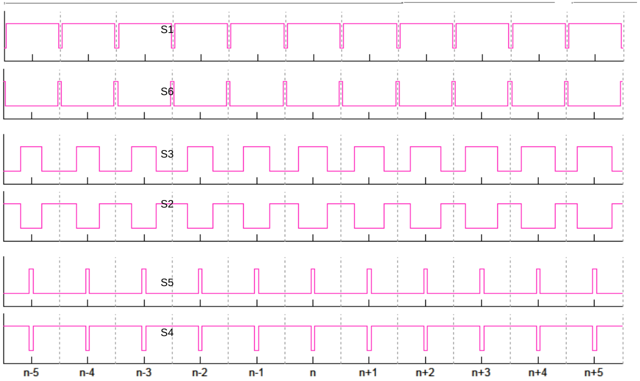


Fig.10. Space vector pulses generation of proposed VSMC

In this section, a very sparse matrix converter with different Load Conditions resistive and resistive inductive load using indirect space vector modulation (ISVM) is analyzed. . the simulated response of the very sparse matrix converters using indirect Space Vector Modulation (ISVM) with R and RL load for a modulation index of 0.9.

IV SIMULATED RESULTS OF VSMC USING ISVM FOR VARIOUS MODULATION INDICES

The simulated input waveforms of chosen very sparse matrix converter using ISVM with R and RL load for modulation index (m_a) 0.9 is shown in Fig.11 and 15 From the observation of both figure it is found that the input voltage of the converter is smooth in form, but the input current is distorted in shape in both R and RL load due to the presence of input harmonics on the source side.Fig .12 displays the output voltage and current waveform of very sparse matrix converter involving ISVM strategy. From this figure, it is observed that the voltage and current waveform are smooth with the presence of very less distortion due to switching modulation of the proposed converter topology. The same results are repeated for RL load, which is shown in Fig.16.The Fig.13. represents the voltage harmonics of very sparse matrix converter involving ISVM with R load.

From this figure, it is observed that the percentage of total harmonic voltage are reduced to 4.79% with RMS voltage of 79.49.Similarly the percentage of total harmonic distortion for current reduced to 14.72% with RMS current value of 0.028 as shown in figure 4.12. Figure 6.15 displays that percentage of total harmonic distortion of very sparse matrix converter using ISVM with RL is load reduced to 4.94% with RMS voltage of 76.58.The current harmonic distortion of very sparse matrix converter involving ISVM with RL load for the modulation index (m_a) 0.9 is reduced to 3.20% with RMS current value of 0.4147 as portrayed in figure 6.16

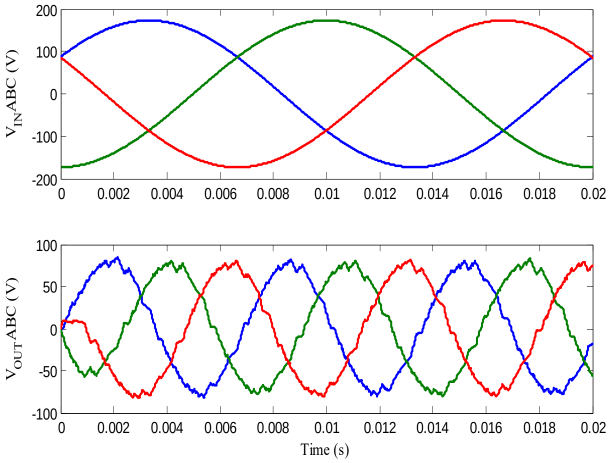


Fig.11. Simulated input voltage and current response of VSMC using ISVM with R Load for ma=0.9

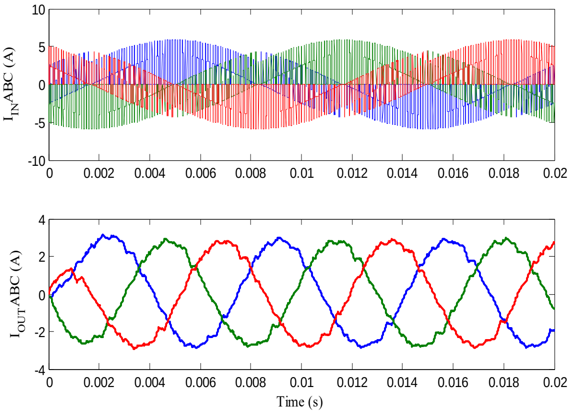


Fig.12. Simulated output voltage and current response of VSMC using ISVM with R Load for ma=0.9

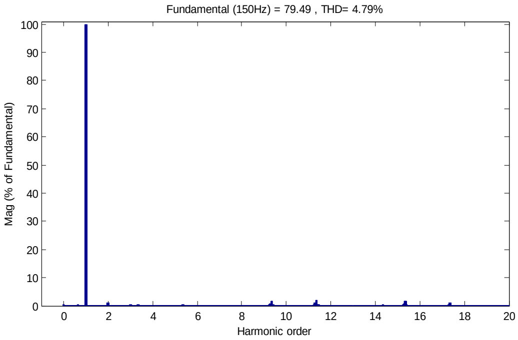


Fig.13. Simulated voltage harmonic response of VSMC using ISVM with R Load for ma=0.9

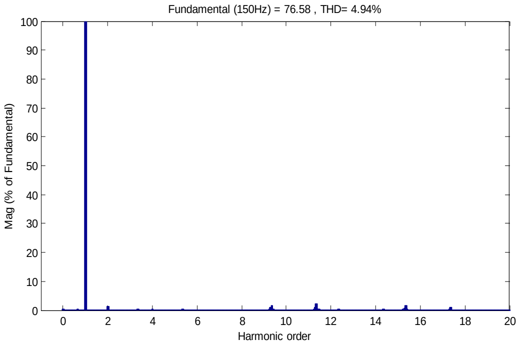


Fig.14. Simulated current harmonic response of VSMC using ISVM with R Load for ma=0.9

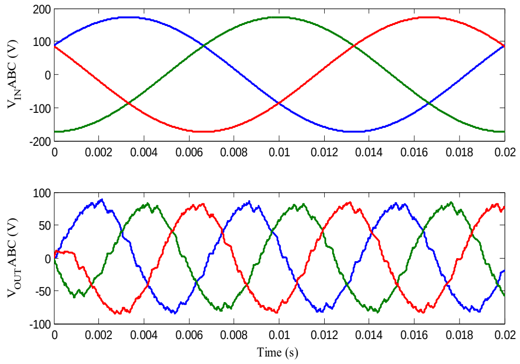


Fig.15. Simulated input voltage and current response of VSMC using ISVM with RL Load for ma=0.9

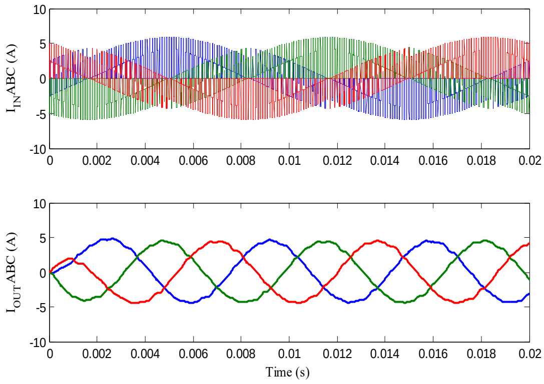


Fig.16 Simulated output voltage and current response of VSMC using ISVM with RL Load for ma=0.9

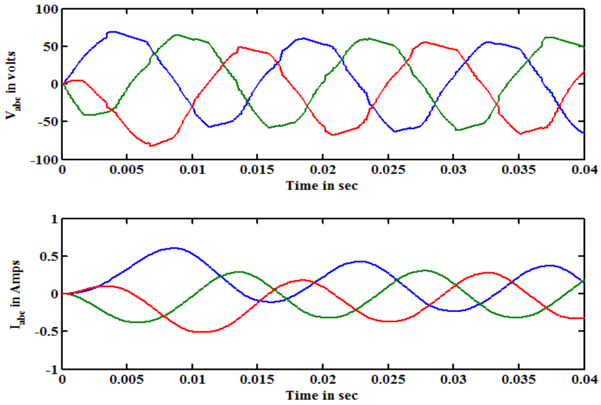


Fig.17 Simulated load voltage and current response of VSMC using ISVM

The simulations are carried out under different modulation index both for R and RL load using ISVM strategy involving VSMC. For evaluation purpose, the different modulation strategies voltage and current THD's are considered along with the fundamental component of Vrms and Irms. The performance measures obtained for VSMC with CSVM strategy under different modulation index are listed in Table .1

Table.1 Simulated performance measures of VSMC using ISVM

Type of Matrix Converter	**Modulation index (m_a)**	**Type of load**	**Performance Measures**			
			Vrms	**Irms**	**% THD (V)**	**%THD (I)**
VSMC	0.9	R	79.49	0.0282	4.79	4.72
		RL	76.58	4.417	4.94	3.2
	0.8	R	69.81	0.0247	5.1	5.04
		RL	67.2	3.873	5.25	3.27
	0.5	R	44.81	0.478	7.01	9.06
		RL	44.07	0.253	7.15	7.84
	0.4	R	34.89	0.201	8.15	9.99
		RL	34.51	0.198	8.28	8.29

Table 2. Simulated FFT analysis for current Harmonics of indirect sparse matrix converter for various loads with CSVM

Modulation Index (m_a) = 0.8	Percentage of Current Harmonics(V_{THD})
R LOAD	24.31
RL LOAD	22.88
MOTOR LOAD	3.11

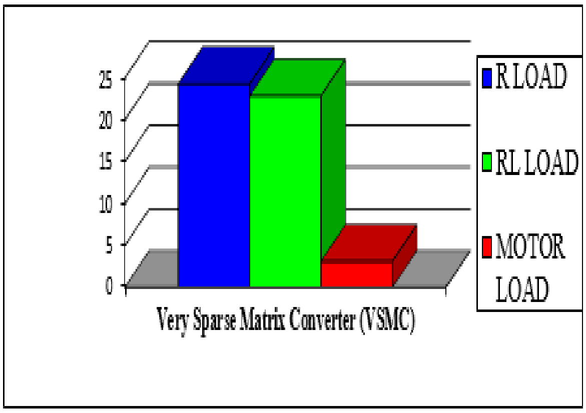
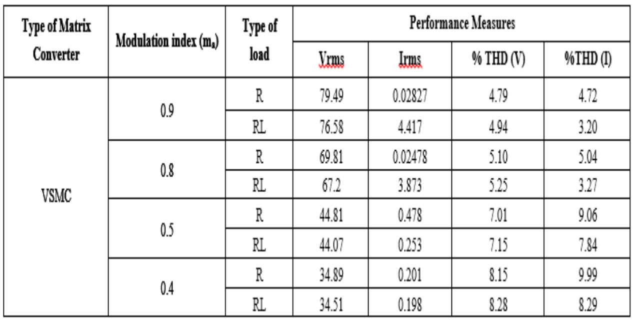


Fig.18. Graphical representation of Simulated FFT analysis for Current Harmonics of indirect sparse matrix converter for various loads with CSVM

Table .3 Simulated performance measures of VSMC using ISVM



Type of Matrix Converter	Modulation index (m_a)	Type of load	Performance Measures			
			Vrms	Irms	% THD (V)	%THD (I)
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		RL	76.58	4.417	4.94	3.20
	0.8	R	69.81	0.02478	5.10	5.04
		RL	67.2	3.873	5.25	3.27
	0.5	R	44.81	0.478	7.01	9.06
		RL	44.07	0.253	7.15	7.84
	0.4	R	34.89	0.201	8.15	9.99
		RL	34.51	0.198	8.28	8.29

V CONCLUSION

Performance evaluation of Very Sparse Matrix converter (VSMC)is carried out with different Load Conditions (R and RL) using space vector modulation techniques using Indirect Space Vector Modulation (ISVM) techniques are applied to Very Sparse Matrix Converter topology for different modulation index . From that it is observed that very sparse matrix converter generated lower THD, Providing better output waveforms Performance both voltage and current.

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