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Performance analysis of Very Sparse Matrix Converter using ECSVM method

*R. Natarajan[*1], B. Baskaran[2] and G. Irusapparajan[3]*

[1]Research Scholar, Dept. of EEE, Annamalai University,
Annamalai Nagar – 608002, Tamil Nadu, India
natarajarphd@gmail.com

[2]Professor, Dept. of EEE, Annamalai University,
Annamalai Nagar – 608002, Tamil Nadu, India
baskarancdm@gmail.com

[3]Professor, Dept. of EEE, Mailam Engineering College,
Villupuram – 604 704, Tamil Nadu, India
irusgkm@gmail.com

Abstract: ***Matrix converters are frequency converters which do not contain a direct current link circuit with passive components, unlike conventional frequency converters. Thus, matrix converters may provide 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. The matrix converter (MC) is an alternative AC-AC power converter by connecting the direct input to output phases through bidirectional switches and without using any dc-link or energy storing element, therefore, is called an all-silicon converter. Two topologies of matrix converter are established such as linear topology and the indirect topology. This paper is devoting to presents the topology of the Very Sparse Matrix Converter (VSMC). The article is focused on Easy Commutation Space Vector Modulation (ECSVM) modelling applied to the very sparse matrix converter (VSMC).***

Keywords: *Indirect Matrix Converter, Easy Commutation Space Vector Modulation, Total Harmonic Distortion.*

1. Introduction

The Indirect Matrix Converter (IMC) is a modern direct converter of AC/AC electrical power without the dc-link capacitor. It consists of a matrix of bi-directional switches arranged such that any input phase can be connected to any output phase at any point in time. It ensures bidirectional power flow between the network and the receiver load with a control of the output voltage amplitude and frequency [1-8]. So, matrix converter provides a modifiable input power factor and high-quality sine waveform through to a matrix structure of bidirectional power switches in current and voltage, in each output phase is real to each input phase. Matrix converter has a die significant interest since appeared in 1976 especially during the last decade. View the advantage of IMC compared to conventional converters such as cyclo-converter, dimmer and conventional converter. Indirect Matrix Converter has advantages of

- A wide range of operating frequency to the output voltage
- A variable ratio between the output and input voltage can be maximized at possible
- The decouple controlling of output voltage amplitude and frequency
- A reduced total harmonic distortion also for the input and output currents
- Input and output current and voltage sine waves with an adjustable phase shift, so the ability to operate at unity power factor for any load
- Operation in all four quadrants
- The absence of a large capacitor for filtering and energy storage, bulky, heavy and susceptible to failure, which reduces the cost and design of the converter
- Operation at high temperature
- Gain reliability.

All these advantages facilitate the integration of this new converter topology in several areas of industrial applications such as aerospace industries that have a significant interest in this converter, industries marine propulsion, the electric drive variable speed machines, embedded systems and renewable energy field based the wind and fuel cells [9-11]. In this paper, a very sparse indirect matrix converter is developed, and results are obtained for R load. Simulation results are discussed, and the performance of the very sparse indirect matrix converter topology is therefore evaluated.

2. Indirect matrix converter

The indirect matrix converter (IMC) has received considerable attention as it provides an excellent alternative to double-sided PWM voltage source rectifier-inverter having the advantage of being a two stage converter with six bidirectional switches and six unidirectional switches. For three phase to three phase conversion and inherent bidirectional power flow, sinusoidal input/output waveforms with modulating switching frequency, the possibility of compact design due to the absence of dc-link reactive components and controllable input power factor independent of output load current. The main disadvantages of matrix converter are the inherent restriction of the voltage transfer ratio (0.866), more complex control and protection strategy.

3. Very Sparse Matrix Converter

The Characteristics of Very Sparse Matrix Converter Topology includes 12 Transistors and 30 Diodes. There is no limitation in functionality compared with the Direct Matrix Converter and Sparse Matrix Converter. When compared to the Sparse Matrix Converter it uses reduced number of transistors but increases the conduction losses due to some diodes in the conduction paths. Figure.1 shows the circuit diagram of Very Sparse Matrix Converter.

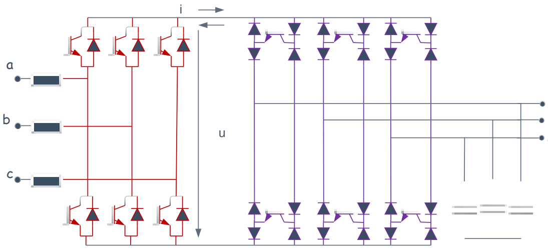

Figure 1: Very Sparse Matrix Converter

4. Easy Commutation Space Vector Modulation (ECSVM)

The IMC can be modulated so that the special commutation methods are not required in the supply-side bridge of indirect matrix converter. It is brought about in such a way that the state of a real supply-side bridge of indirect matrix converter, i.e. duty cycle change from d_γ to d_δ and vice versa, is performed in the middle of the duty cycle d_0 performed by the load-side bridge of indirect matrix converter [12-14]. The method is called the easy commutation space vector modulation method (ECSVM) and its principle is presented in Tables 1 and 2 in the row 'ECSVM'.

Comparing the ECSVM pulse patterns in Table 2 with the input phase voltages in Figure 2 and deriving the patterns for all sector combinations, it can be found that the ECSVM produces the zero states which connect the input voltage with the highest magnitude, i.e. $u_{i,max.}$ when $|u_{i,max}| > |u_{i,min}|$ and $u_{i,min}$ when $|u_{i,max}| < |u_{i,min}|$, to every output phase, resulting always in the maximum common-mode voltage of $\hat{u}_i$, i.e. ±275 V. Thus, the ECSVM is not an optimum solution for common-mode voltages. Also, the ECSVM does not provide safe commutation when the duration of the zero duty cycle is not long enough for the commutation of the supply-side bridge of indirect matrix converter. Thus, the ECSVM must always contain a zero state, which limits the attainable maximum output voltage.

Table 1: Duty cycle patterns of ECSVM method considered.

Method	Sum of Sectors	State 1	State 2	State 3	State 4	State 5	State 6
ECSVM	Even	$d_{\gamma\kappa}/2$	$d_{\gamma\lambda}/2$	$d_0/2$	$d_{\delta\lambda}/2$	$d_{\delta\kappa}$	$d_{\delta\lambda}/2$
	Odd	$d_{\gamma\lambda}/2$	$d_{\gamma\kappa}/2$	$d_0/2$	$d_{\delta\kappa}/2$	$d_{\delta\kappa}$	$d_{\delta\kappa}/2$

Table 2: Examples of supply phases connected to output phases with ECSVM method.

Voltage Sector	Current Sector	State 1	State 2	State 3	State 4	State 5
		ABC	ABC	ABC	ABC	ABC
I	1	abb	aab	aaa	aac	acc
	2	aac	acc	ccc	bcc	bbc
	3	bcc	bbc	bbb	bba	baa
	4	bba	baa	aaa	caa	cca
	5	caa	cca	ccc	ccb	cbb
	6	ccb	cbb	bbb	abb	aab
II	1	bab	aab	aaa	aac	cac
	2	aac	cac	ccc	cbc	bbc
	3	cbc	bbc	bbb	bba	aba
	4	bba	aba	aaa	aca	cca
	5	aca	cca	ccc	ccb	bcb
	6	ccb	bcb	bbb	bab	aab

5. Simulation results

Performance evaluation of Very Sparse Matrix Converter (VSMC) with R Load Condition using easy commutation Space Vector Modulation (ECSVM) is carried out using MATLAB/Simulink. Switching pulses for the proposed converter is generated using easy commutation Space Vector Modulation (ECSVM). The structure of very sparse matrix converter (VSMC) are assigned to be having the parameters of on load side end having MI = 0.8 frequency =150 Hz and fc=2 kHz. Figs.2-4 shows the simulated response of the very sparse matrix converters using easy commutation Space Vector Modulation (ECSVM).

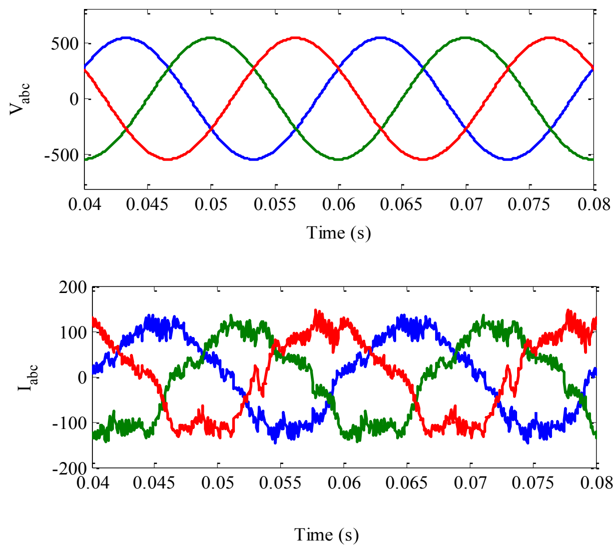

Figure 2: Input Voltage and Current response of very sparse matrix converter with R Load

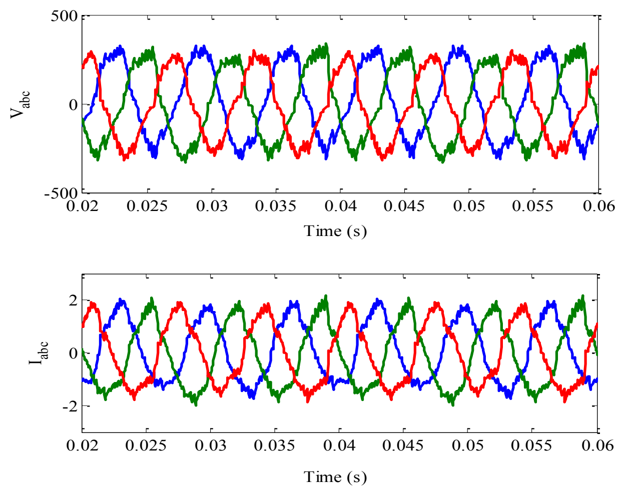

Figure 3: Output Voltage and Current response of very sparse matrix converter with R Load

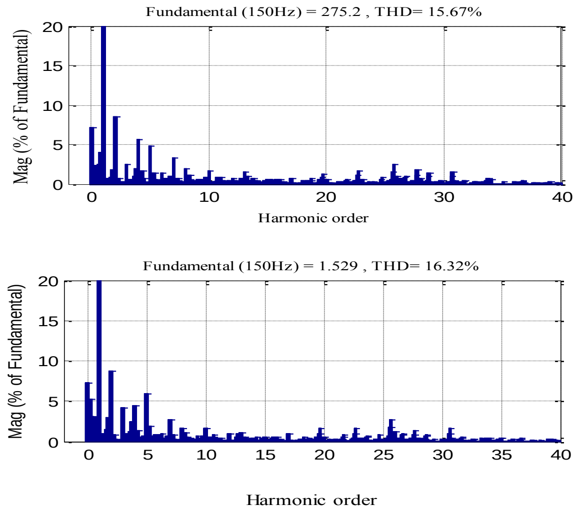

Figure 4: Output Voltage and Current harmonic response of very sparse matrix converter with R Load

Figures.2 and 3 show the voltage and current of source and load for very sparse matrix converter using easy commutation Space Vector Modulation (ECSVM) with R load and Figure. 4 show the voltage and current harmonic analysis of the very sparse matrix converter with R load. From the results Total Harmonic Distortion (THD in %) is considered to evaluate the performance of Very Sparse Matrix Converter is calculated using FFT analysis. From the results, it is observed that the voltage profile of very sparse matrix converter is increased by 276 V using easy commutation Space Vector Modulation (ECSVM). Also, it produced %THD is 15.67%.

6. Conclusion

This paper has presented the indirect matrix converter and its control using the easy commutation Space Vector Modulation method. The harmonic analysis of very sparse matrix converter using easy commutation Space Vector Modulation (ECSVM) with R load has been evaluated. From the analysis, the proposed very sparse matrix converter performed superior in easy commutation Space Vector Modulation (ECSVM) and produced a voltage of ±276. The model is presented step-by-step and in a very clear way following the easy commutation Space Vector Modulation (ECSVM) algorithm and enabling an easy future implementation using a real-time workshop for FPGA programming.

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Author Profile

R. Natarajan was born in Virudhachalam, India in 1986. He has obtained Bachelor of Electrical and Electronics Engineering and Master of Engineering in Power Electronics and Drives from Anna University, Chennai in 2007 and 2009 respectively. Currently, he is pursuing Ph.D. in Annamalai University. He is doing his research work in the area of Matrix converters and its applications.

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B. Baskaran was born in Nagapattinam, India in 1963. He has obtained Bachelor of Electrical and Electronics Engineering, Master of Engineering in Power Systems and Ph.D. from Annamalai University in 1985, 1991 and 2013 respectively. Currently, he is a professor in the Department of Electrical Engineering, Annamalai University. Where he has put in a total service of 27 years since 1987. He has published more than six international and national journals. His area of interest includes modelling, simulation and intelligent control for matrix converter.

G. Irusapparajan received his B.E. Degree from Manonmaniam Sundaranar University in 2000, M.E degree from Annamalai University in 2005, M.H.R.M., from Annamalai University in 2008. He was received his Ph.D. from Bharath University in 2011, in the area of Power System. He has more than 11 years of teaching experience. He has published ten research papers in reputed international journals and conferences. His research areas are FACTS and Power Electronic Drives. He now with DDI Tokyo Pocket Telephone, Inc.

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