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A Neuro-Fuzzy Logic Control of Three Phase to Single Phase Matrix Converter fed Induction Heating System

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Abstract:

Advancement of power semiconductor devices paved way for development of direct AC-AC conversion topology which has wide application range than conventional AC-DC-AC converters as they restrict the usage of DC link components. In this manuscript modeling and simulation of a Neuro-Fuzzy Logic Controlled (NFLC) three phase (TPMC) to Single Phase Matrix Converter (SPMC) fed Induction Heating (IH) system is illustrated. The performance of the system for various operating frequencies of the Single Phase Matrix Converter in the MATLAB/Simulink environment is presented in this paper. Pulse Width Modulation (PWM) control strategy is employed for converter switching topology by Neuro-Fuzzy logic control over a constant voltage, constant frequency input supply of the converter. The simulation results exhibit the enhanced performance of the system over the conventional AC-DC-AC converter topologies yielding a low THD for various output frequencies of the converter.

Keywords:
Single Phase Matrix Converter, Neuro-Fuzzy Logic Control, Induction Heating, Pulse Width Modulation.

I. Introduction

Induction Heating (IH) systems have been widelyused in domestic and industrial applicationsas it has higher throughput, efficiency, faster and non-polluting system.Induction heating systems play a major part in various industrial applications such as melting, forging, hardening, tempering, annealing, brazing, bonding, welding, specialty heating, plastic injection molding, etc., and in domestic applications such as cooking, boiling, and super heating applications. A typical Induction Heating [1-4] system requires high frequency AC supply for which transformers or motor-generator sets or AC – AC converters or AC – DC – AC converters were being employed.

The direct AC – AC convertersalso termed asMatrix Converters (MC) [3-15] when compared to DC link converters such as Voltage Source Inverters (VSI) and Current Source Inverters (CSI) possesses more advantage such as wide range of operating frequency, variable output voltage magnitude for a given fixed frequency and fixed voltage input supply without any intermediary DC link due to direct conversion of AC – AC, which is highly advantages for these type of converters over other conventional converter and the development of fast and efficient switching devices such as SCR, GTO, MOSFET and IGBT’s paved way for using these AC – AC converters in practice effectively.

In this article Neuro-Fuzzy Logic Control (NFLC) technique is employed to control the switching strategy of the Single Phase Matrix Converter (SPMC) [11-15]. The modelling and performance of the system for various operating output frequencies is presented in the following sections.

II. Single Phase Matrix Converter

The matrix converter [5-6], [9], [11-15]replaces multiple conversion stages disparateto VSI and CSI rectifier and inverter stages and eliminates bulk storage elements as DC link by a single-direct power conversion stage. Single phase matrix converter has four bidirectional switches connecting the each phase of source to each phase of load, arranged in two groups of two switches as shown in following figure 1. This switching arrangement can connect any input phase to any output phase.

The bidirectional switching arrangement can be of three different structures modeled with IGBT and protective diodes. A bridge diode with single IGBT switch and two diodes with two IGBT connected in antiparallel combination with common emitter or common collector forms the switching arrangement. In this article a common emitter model of bidirectional switching arrangement as shown in figure 2 is utilized in the single phase matrix converter system.

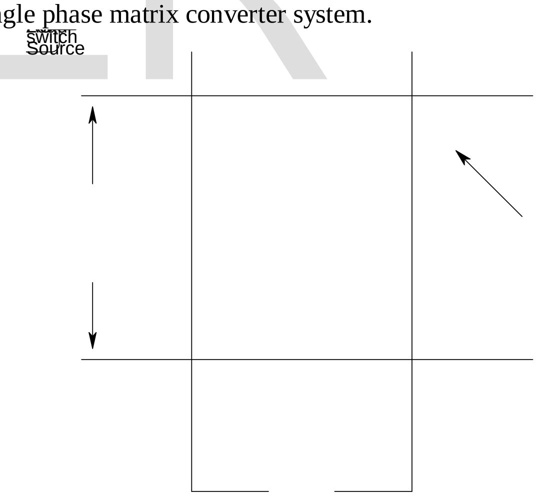

Figure 1: Single Phase Matrix Converter (SPMC) arrangement

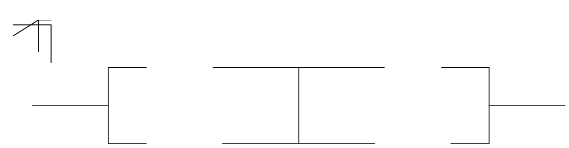

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Figure 2: Bidirectional switch Common emitter back to back arrangement

Typically a SPMC shown in figure 3 is fed by a voltage source whose input terminals should not be short circuited to avoid damage to the input source due to short circuit high current and the output phase should not be open circuited due to the flow of inductive load current which will lead to over voltage. The switching state of SPMC is shown in table I.

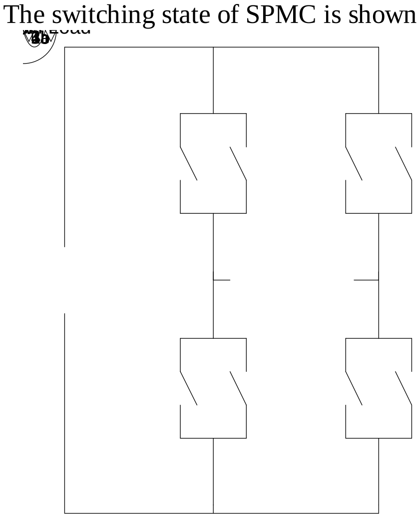

Figure 3: Basic block diagram of SPMC

Table I: Switching state combination in SPMC

Input frequency	Output frequency	Time Interval	Switching mode
50 Hz	25 Hz	1	$S_{1a} - S_{4a}$
		2	$S_{3b} - S_{2b}$
		3	$S_{2a} - S_{3a}$
		4	$S_{4b} - S_{1b}$
	50 Hz	1	$S_{1a} - S_{4a}$
		2	$S_{4b} - S_{1b}$
	100 Hz	1	$S_{1a} - S_{4a}$
		2	$S_{2a} - S_{3a}$
		3	$S_{3b} - S_{2b}$
		4	$S_{4b} - S_{1b}$

III. Neuro-Fuzzy Logic Controller Modelling for Three Phase to Single Phase Matrix Converter

The Neuro-Fuzzy logic controller to control single phase matrix converter switching sequence is shown in the following block diagram in figure 4. The three phase source is rectified by a high frequency rectifier and inverted to AC quantity by a single phase inverter which is fed to SPMC controlled by a Neuro-Fuzzy Logic Controller. The output of the SPMC is connected to a single phase load as shown in figure 4.

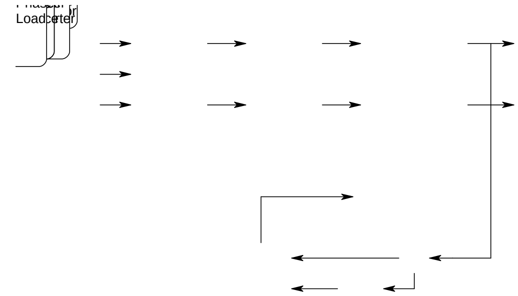

Figure 4: Neuro-Fuzzy Logic Control block diagram

The Neuro-Fuzzy controller takes the error in output load current and computes the change in error and the two inputs are fed to NFLC which generates control signal to produce PWM signals through the switching sequence generator and the output signal is fed to the single phase matrix converter which is connected to the induction heating system.The input signals error and change in error are classified into five membership functions Negative Big (NB), Negative Medium (NM), Zero (ZE), Positive Medium (PM) and Positive Big (PB) as shown in following figures 5 and 6.

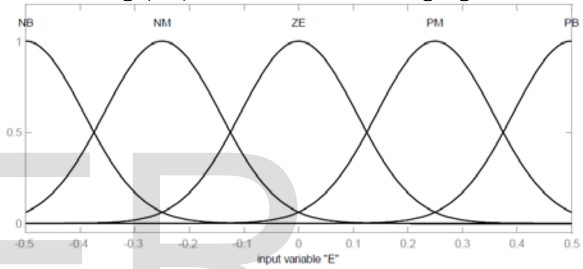

Figure 5: Fuzzy membership function for error

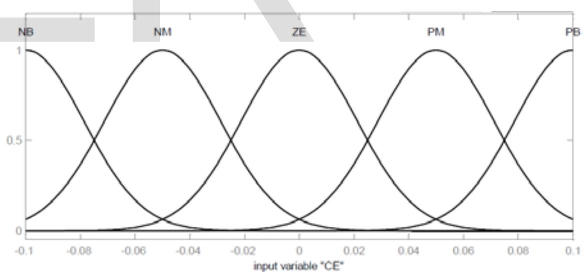

Figure 6: Fuzzy membership function for change in error

The Neuro-Fuzzy Logic Controller (NFLC) architecture is trained by back propagation technique based on grid partition of the input and output membership functions. The training output is shown in figure 7 below. Figure 8 shows the surface view of the Neuro-Fuzzy inference system after training.

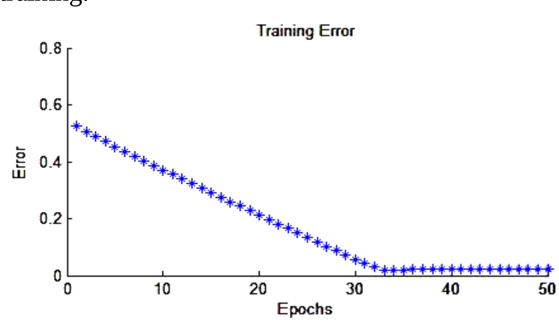

Figure 7: Neuro-Fuzzy training output

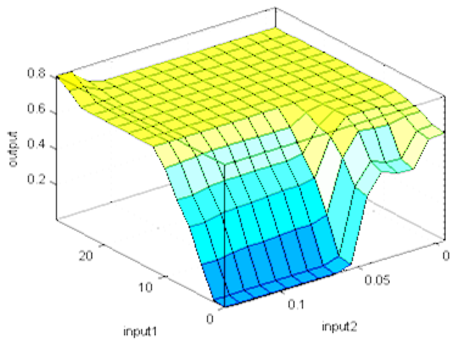

Figure 8: Fuzzy rule base surface view

IV. Results and Discussion

The results obtained from the three phase to single phase matrix converter fed induction heating system for an induction heating load of L=1mH and R=2ohms is shown in following figures 9 to 16 for various output frequencies. Figure 9 shows the line voltage output of the single phase matrix converter for 25Hz output frequency and figure 10 shows the corresponding output current waveform obtained from the Simulink environment.

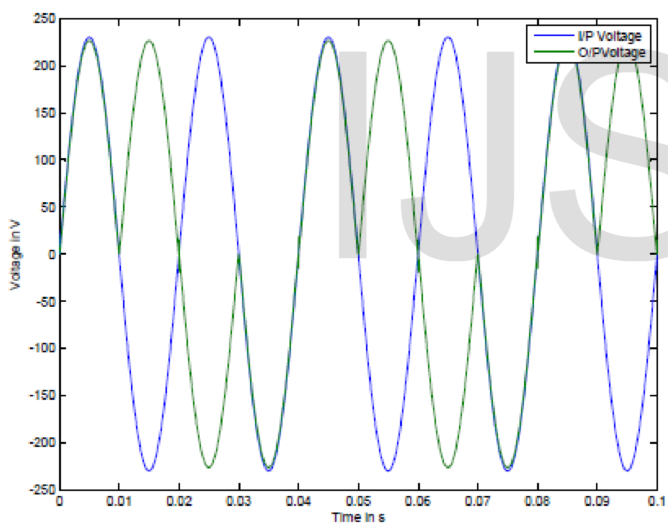

Figure 9: Input and Output Voltagewaveform for 25 Hz

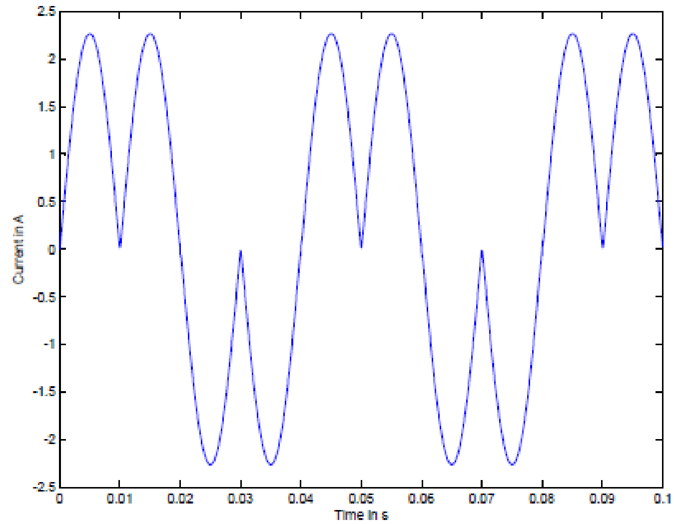

Figure 10: Output Current waveform for 25 Hz

The input and output voltage waveform of single phase matrix converter for 50 Hz output is shown in figure 11. Figure 12 shows the output current waveform of the single phase matrix converter for 50 Hz frequency.

The input and output voltage waveform of single phase matrix converter for 100 Hz output is shown in figure 13. Figure 14 shows the output current waveform of the single phase matrix converter for 100 Hz frequency.

The input and output voltage waveform of single phase matrix converter for 500 Hz output is shown in figure 15. Figure 16 shows the output current waveform of the single phase matrix converter for 500 Hz frequency.

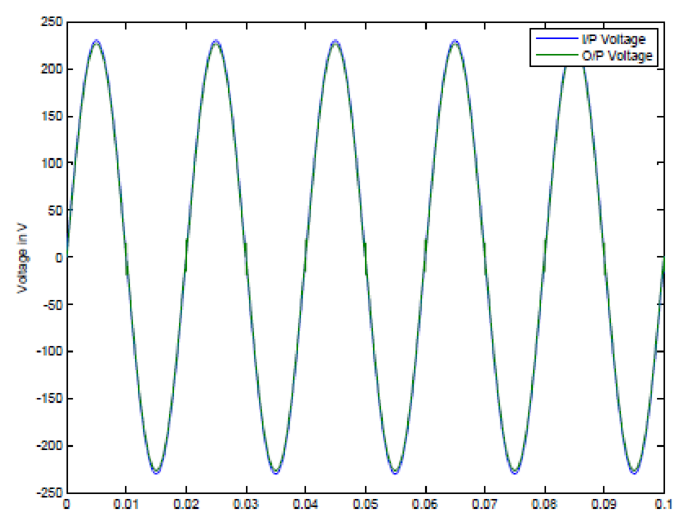

Figure 11: Input and Output Voltage waveform for 50 Hz

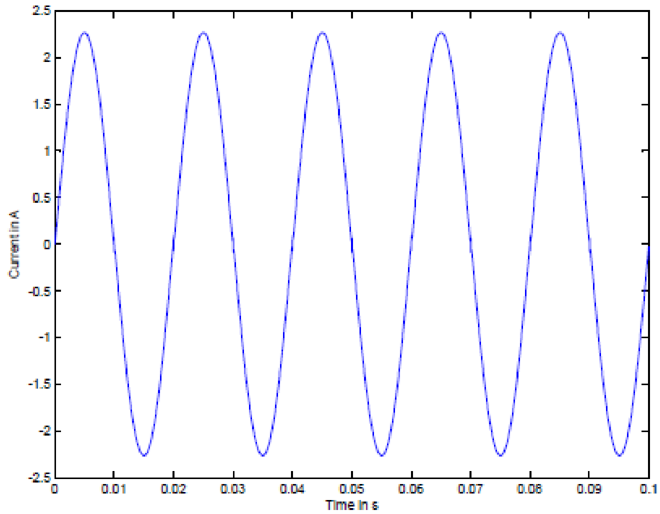

Figure 12: Output Current waveform for 50 Hz

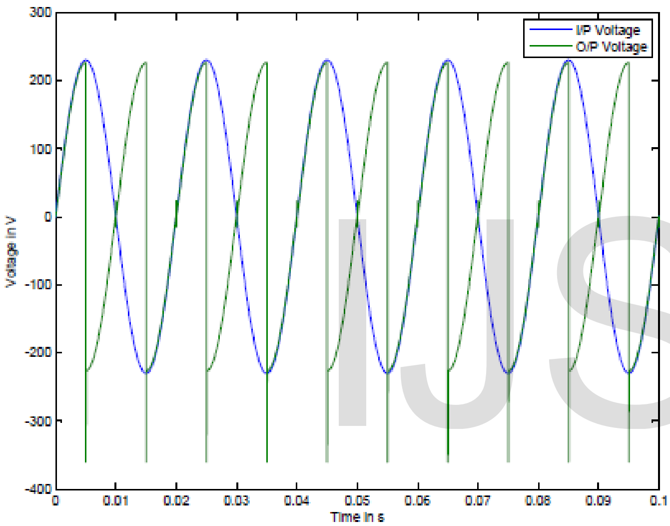

Figure 13: Input and Output Voltage waveform for 100 Hz

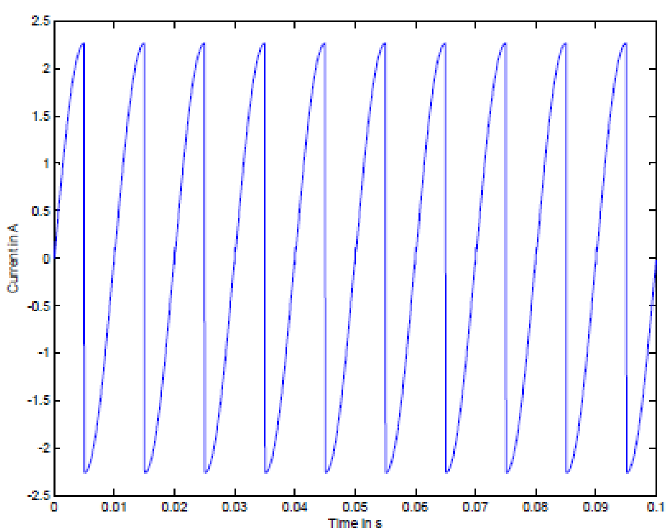

Figure 14: Output Current waveform for 100 Hz

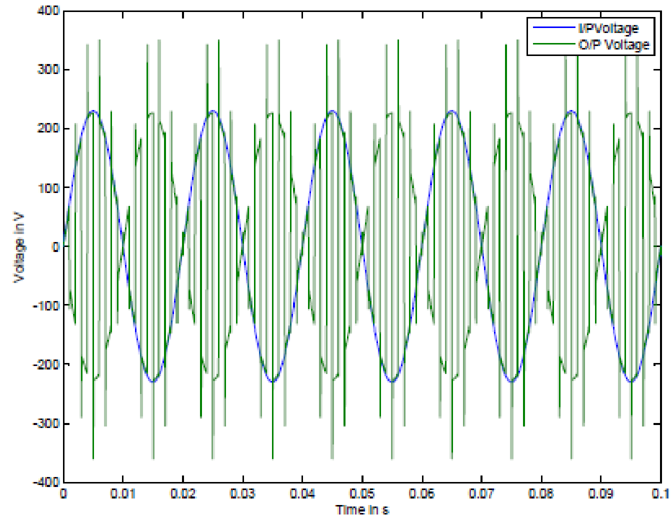

Figure 15: Input and Output Voltage waveform for 500 Hz

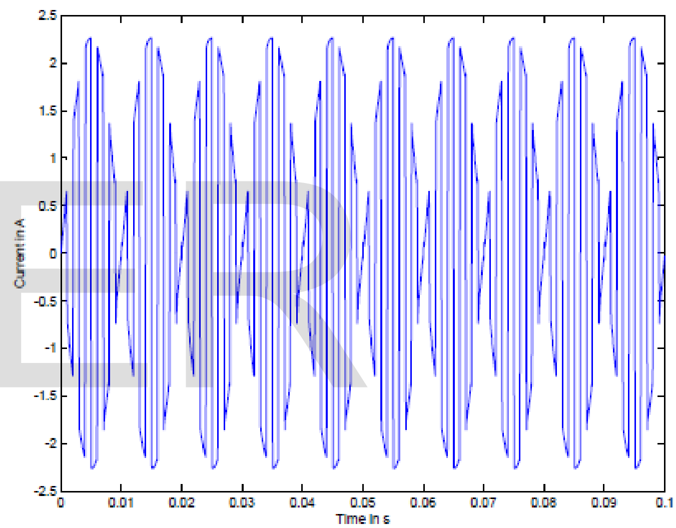

Figure 16: Output Current waveform for 500 Hz

The following table IIshows the Total Harmonic Distortion (THD) obtained from the three phase to single phase matrix converter output.

Table II: THD Vs Operating Frequencies of FLC Controller

S. No	Frequency in Hz	THD in %
1	25	32.8
2	50	25.6
3	100	18.2
4	500	14.6

V. Conclusion

The results obtained from the NFLC controlled three phase to single phase matrix converter fed induction heating system in the Simulink environment depicts the robust operation of the converter and the low optimum THD is obtained from the converter output.

Reference

[1] Mollov S. V., Theodoridis M., Forsyth A. J. “High frequency voltage-fed inverter with phase-shift control for induction heating”, *IEE Proc.-Electr. Power Appl.* Vol. 15, January 2004

[2] Saichol Chudjuarjeen, Anawach Sangswang, and Chayant Koompai, “An Improved LLC Resonant Inverter for Induction Heating with Asymmetrical Control”, Seoul Olympic Parktel, Seoul, 2009, pp.1612-1617

[3] Hisayuki Sugimura, Sang-Pil Mun, Soon-Kurl Kwon, Tomokazu Mishima, Mutsuo Nakaoka, “High-Frequency Resonant Matrix Converter using One-Chip Reverse Blocking IGBT-Based Bidirectional Switches for Induction Heating”, *IEEE*, pp.3960-3966, 2008

[4] N. Nguyen-Quang, D.A. Stone, C.M. Bingham, M.P. Foster, “Comparison of single-phase matrix converter and H-bridge converter for radio frequency induction heating”, *IEEE International Symposium on Industrial Electronics (ISlE)*, 2009

[5] Mahmoud Hamouda, Farhat Fnaiech, Kamal Al-Haddad, “Input-State Feedback Linearization Control of Three-Phase Dual-Bridge Matrix Converters Operating Under Unbalanced Source Voltages”, *IREMOS*, Vol. 4, 2011, pp. 467-477

[6] Majid Aghasi, Vahid Faraji, Hamid Behnia, Davood Arab Khaburi Ali Dehghan Banadaki, “Predictive DTC-ISVM for Doubly-Fed Induction Machine System Fed by Indirect Matrix Converter”, *IREMOS*, Vol. 5, 2012, pp.854-864

[7] Sedat Sünter, Ömür Aydo˘gmu¸s, “Implementation of a single-phase matrix converter induction motor drive”, *Electr Eng.*, Vol. 90, 2008, pp.425–433

[8] M.Senthil Kumaran, R.Siddharth, M.Stalin, A.Divakhar, Ranganath Muthu,“Constant Pulse Width Switching Strategy for Matrix Converter”, *IREMOS*,Vol. 4, 2011, pp.2954-2960

[9] A. Djahbar, B. Mazari,“Matrix Converter for Six-Phase Induction Machine Drive System”, *IREMOS*, Vol. 2, 2007, pp.232-241

[10] N. Nguyen-Quang, D.A. Stone, C.M. Bingham, and M.P. Foster, “A three-phase to single-phase matrix converter for high-frequency induction heating”, 2009

[11] Wheeler P. W., Rodriguez J., Clare J. C., Empringham L., Weinstein A, “Matrix Converters: A Technology Review”, *IEEE Trans. Ind. Electron.* Vol. 49, 2002, pp.276-288

[12] Kim S., Sul S. -K., Lipo T. A, “AC/AC Power Conversion Based on Matrix Converter Topology with Unidirectional Switches”, *IEEE Trans. Ind. Appl*. Vol. 36, 2000, pp.139-145

[13] Mutschler P., Marcks M. “A Direct Control Method for Matrix Converters”, *IEEE Trans. Ind. Electron.* Vol. 49, pp.362-369

[14] Zhang L., Watthanasarn C., Shepherd W. “Analysis and comparison of control techniques for AC-AC matrix converters”, *IEE Proc.-Electr. Power Appl.* Vol. 145, 1998, pp.284-294

[15] Nguyen-Quang N., Stone D. A., Bingham C. M., Foster M. P. “Single phase matrix converter for radio frequency induction heating”, SPEEDAM 2006, pp.614-618