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Simulation of Single Phase Matrix Converter as DC-DC and DC-AC Converters

Gokturk Ozturk[1], Guven Onbilgin[2]
[1]Department of Energy Systems Engineering, Recep Tayyip Erdogan University
Rize, Turkey
gokturkozturk@yahoo.com
[2]Department of Electrical and Electronics Engineering, Ondokuz Mayis University
Samsun, Turkey
gonbilgi@omu.edu.tr

Abstract **–** In this study, simulation of a DC-DC buck converter and DC-AC converter have been created by using single phase matrix converter topology. Controller and single phase matrix converter circuit are the main parts of system. Controller determines the type of converter according to switching algorithms in its structure. Results and oscilloscope images have been obtained for different parameters.

Keywords**:** Matrix Converter, Simulation, DC-DC Buck Converter, DC-AC Converter.

1. Introduction

Power electronics is one of the rapidly growing areas. Almost all electronic devices are related to power electronics directly. Aim of power electronics are ensuring the voltage and current according to consumer loads in general and controlling the electrical energy. In that case power electronics converters get such an important place.

Nowadays new approaches are getting more attentions beside the conventional converters. Conventional converters have different topologies for different converters such as rectifying and inverting. However, matrix converters remove necessity of different topologies because exactly same design is valid for different functions with matrix converters [1]. Also these power electronic converters have simple design so they have an advantage [2]. Other advantage of matrix converters is containing none or few reactive storage elements in their topology unlike conventional rectifier-inverter based systems [3]. Therefore, matrix converters have great control with the use of power switches that have very high switching frequency.

The topology of matrix converters was created firstly in 1976 by Gyugyi [4]. Venturini improved this in 1980 [5]. However, early studies in this field were about three phase matrix converters. Single phase matrix converter (SPMC) have been studied firstly by Zuckerberger [6]. As seen from researches SPMC can use as DC to DC converter and DC to AC converter [7, 8, 9, 10].

2. System Definition

In base of this study there are design of SPMC and switching algorithms for different converter types. MATLAB/Simulink has been used for design and simulation.

In Figure 1, topology of SPMC has been given. SPMC has four bi-directional switches and to simulate them IGBTs and diodes have been used. IGBTs have been driven with 50 Hz square waves and Pulse Width Modulation (PWM) signals which are obtained via Multiple Pulse Width Modulation (MPWM) method. These four bi-directional switches have been named S1, S2, S3 and S4, so in totally there are eight switches named S1A, S1B, S2A, S2B, S3A, S3B, S4A and S4B.

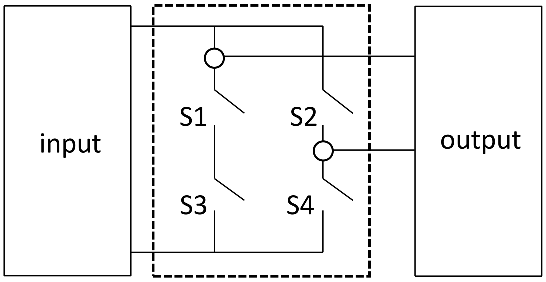

Fig. 1: SPMC topology.

System structure has been given in Figure 2. Two important parts are controller and SPMC blocks. Trigger signals have been generated with controller for SPMC. DC signal values which determined the output voltage magnitude of converters adjust the width of PWM signals.

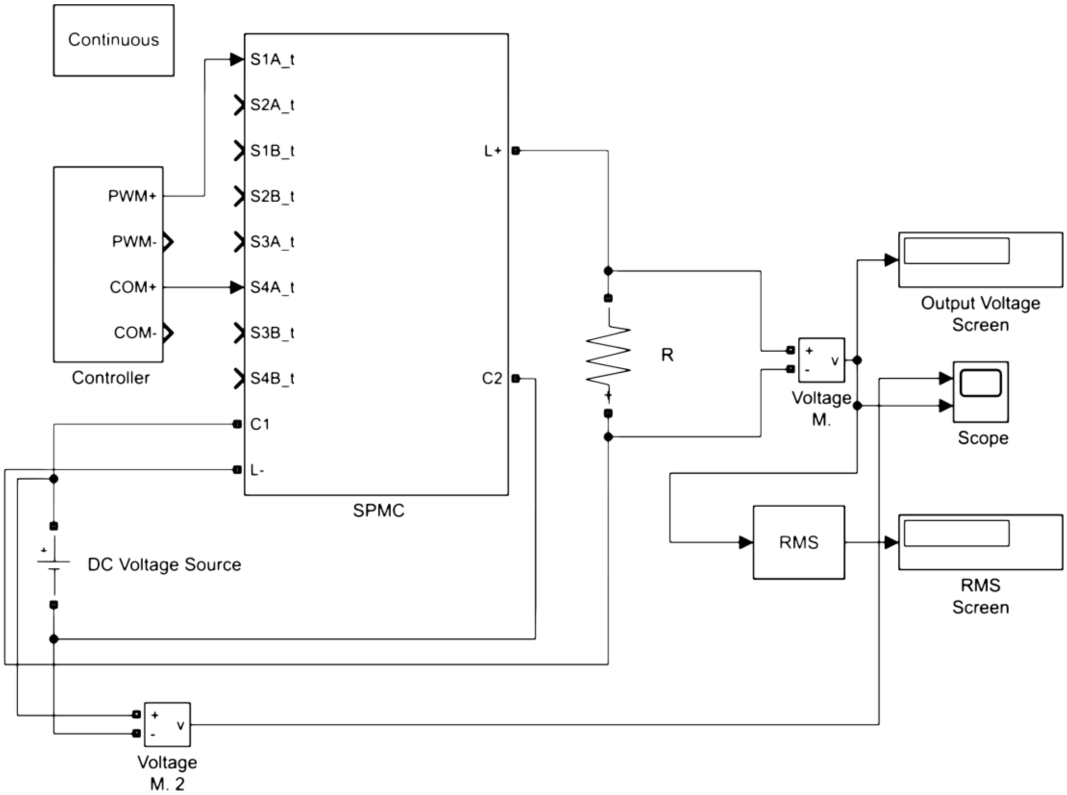

Fig. 2: System structure.

In this study controller has been switched in two different types for two different converters. First of these converters is DC-DC buck converter and second one is DC-AC converter.

2.1. DC-DC Buck Converter

Switching algorithm has been given in Table 1 for this converter. According to this table, S4A switch is in ON mode for positive cycle. S1A switch is in ON mode for positive cycle too, but this switch has been driven with PWM signal.

Table 1: Switching algorithm of DC-DC buck converter.

Sending Signal	Driven Switch
PWM+	S1A
COM+*	S4A

*COM+ is square pulses for positive cycles.

In Figure 3, current flow direction in positive cycle has been given. In negative cycle none of the switches is in ON mode.

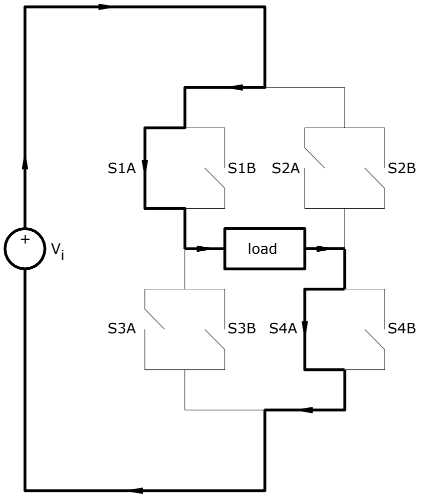

Fig. 3: Current flow direction of DC-DC buck converter in positive cycle.

2.2. DC-AC Converter

Switching algorithm has been given in Table 2 for this converter. According to this table, while S4A switch is in ON mode for positive cycle, S3A switch is in ON mode for negative cycle. S1A and S4A have been driven with PWM pulses.

Table 2: Switching algorithm of DC-AC converter.

Sending Signal	Driven Switch
PWM+	S1A
PWM-	S2A
COM+*	S4A
COM-**	S3A

*COM+ is square pulses for positive cycles, **COM- is square pulses for negative cycles.

In Figure 4, current flow directions in positive and negative cycles have been given. Inverting function is happening as changing direction of current over load for each cycles.

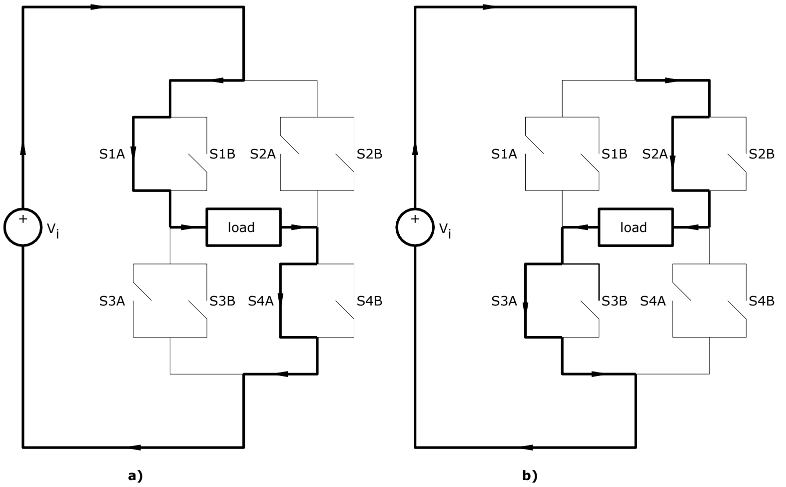

Fig. 4: Current flow directions of DC-AC converter, (a) positive cycle, (b) negative cycle.

3. Results

For DC-DC buck converter, parameters, DC signal values which determined the output voltage magnitude of converter as changing width of PWM signals and voltage values have been given in Table 3.

Table 3: Simulation parameters and data for DC-DC buck converter.

Simulation Number	Input Voltage	Load	DC Signal Magnitude	Output RMS Voltage
1	100 Volt	1 Ohm	0.1 Volt	50.35 Volt
2	100 Volt	1 Ohm	0.3 Volt	54.74 Volt
3	100 Volt	1 Ohm	0.5 Volt	58.80 Volt

In figure 5, oscilloscope images of input and output voltages have been given according to parameters which are 0.3 Volt DC signal value, 100 Volt input voltage and 1 Ohm load.

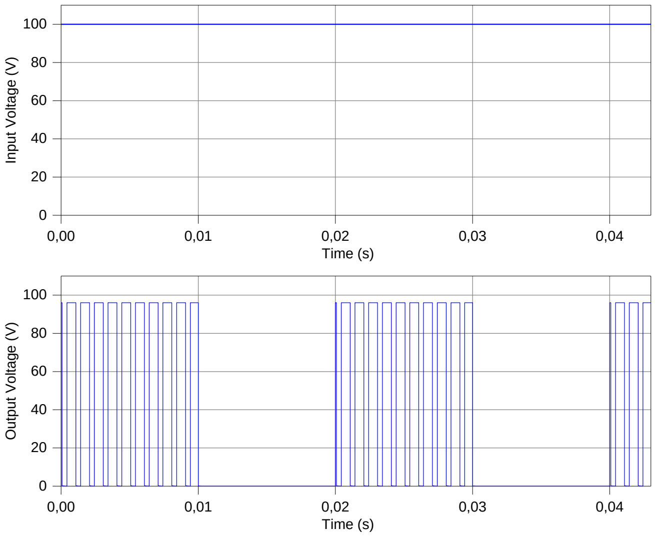

Fig. 5: Oscilloscope images of input and output voltages for simulation number 2 of DC-DC buck converter given in Table 3.

For DC-AC converter, parameters, DC signal values which determined the output voltage magnitude of converter as changing width of PWM signals and voltage values have been given in Table 4.

Table 4: Simulation parameters and data for DC-AC converter.

Simulation Number	Input Voltage	Load	DC Signal Magnitude	Output RMS Voltage	THD
1	100 Volt	1 Ohm	0.1 Volt	71.21 Volt	%47.38
2	100 Volt	1 Ohm	0.3 Volt	77.41 Volt	%43.44
3	100 Volt	1 Ohm	0.5 Volt	83.15 Volt	%44.11

In figure 6, oscilloscope images of input and output voltages have been given according to parameters which are 0.3 Volt DC signal value, 100 Volt input voltage and 1 Ohm load. Also, THD (Total Harmonic Distortion) values have been introduced as percentages in Table 4 for these AC signals.

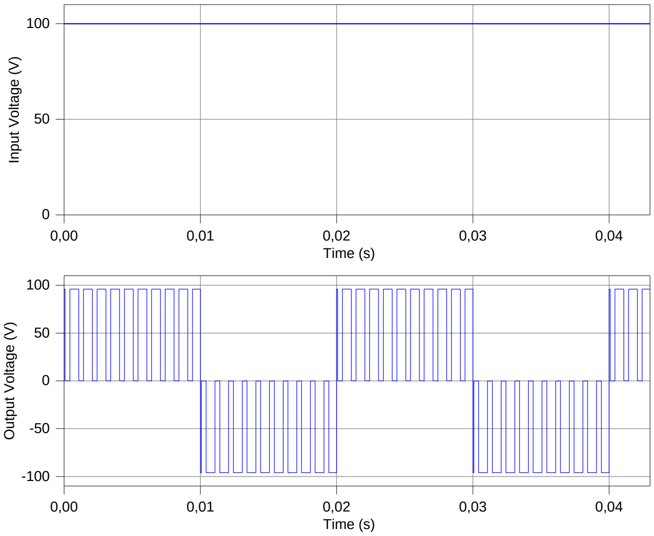

Fig. 6: Oscilloscope images of input and output voltages for simulation number 2 of DC-AC converter given in Table 4.

4. Conclusion

While different designs are required in conventional converters, only one circuit topology is sufficient in matrix converters. In matrix converters different switching algorithms are used for different converting functions.

Switching algorithms and THD values have been introduced for simulations. Output voltage magnitude of converters have been determined by adjustable DC signal which set the width of PWM signals. MPWM method has been used for generating PWM signals.

In conclusion, matrix converter has been obtained in MATLAB/Simulink environment and simulation results show us that DC-DC buck and DC-AC converters have been successfully simulated with matrix converter topology. Moreover, it has been observed that RMS value of output voltage is in direct proportion to DC signal magnitude because of PWM signal width.

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