International Journal of Power Electronics and Drive System (IJPEDS)
Vol. 5, No. 1, July 2014, pp. 129~134
ISSN: 2088-8694

Application of AGPU for Matrix Converters

Nithin T Abraham, C.A Pradeep Kumar, Shaema Lizbeth Mathew
Departement of Electrical and Electronics Engineering, Karunya University, Coimbatore, Tamil Nadu, India

Article Info

Article history:

Received Dec 11, 2013
Revised May 25, 2014
Accepted Jun 2, 2014

Keyword:

Matrix Converter,
sinusoidal PWM,
Aviation ground power unit,
PI control loop.

ABSTRACT

A simple PI control loop for the matrix converter system is designed in the simulation to maintain a constant output voltage inspite of any disturbance in the source. The single phase matrix converter employs a modified safe-commutation strategy, which results in the elimination of voltage spikes on switches, without the need of a snubber circuit when there is an inductive load being utilized. This is facilitated through the proper switching control algorithm. The sine PWM pulses are generated as switching pulses to the converter to reduce the THD.

Corresponding Author:

Nithin T Abraham,
Departement of Electrical and Electronics Engineering,
Karunya University,
Coimbatore,Tamil Nadu,India
Email: nithinthamaravelil@gmail.com

1. INTRODUCTION

The topology was first introduced by Gyugyi and Pelly [1] in 1976. In 1980, Venturini and Alesina described it as a generalized transformer – a bidirectional sinusoidal waveform frequency converter [2]. The single phase version called the Single-phase Matrix Converter (SPMC) was first introduced by Zuckerberger [3], based on the direct AC-AC converter.Static power converters are used for many applications, like frequency converters for motors, uninterruptible power supplies, (UPS), general power supplies and also for Ground Power Units (GPU) for airplanes.A new control strategy for a Ground Power Unit (GPU) is proposed, which is used for airplanes on the ground [4]. The control is performed by a PWM-modulator and a voltage controller. It is concluded from the experiments, that the new controller gives a high output performance both stationary and dynamic, at linear and non-linear loads.In this paper, a SPMC with a modified safe-commutation technique that gives an output of 110V/400 Hz, is designed. As this modified safe-commutation scheme provides a continuous current path in dead time also, it eliminates voltage spikes on switches without the need for a snubber circuit. The operation and basic behaviour of the same is examined through computer simulation. A voltage controller gives the input to the modulator, which controls the converter. The Single Phase Matrix Converter, for voltage applications like the AGPUs, requires step-changed frequency, and/or variable amplitude.

2. AVIATION GROUND POWER UNIT

An Aviation Ground Power Unit supplies airplanes with external electrical power, during stopover in airports. Its application is presently well-established in airports all over the world, primarily due to airport regulations that require the transition to external power in order to reduce acoustic noise and air pollution from jet engines. GPUs have both been built as rotating motor-generator systems and recently as solid-state converters. The solid-state solution has been accepted as a standard, due to low maintenance, lower price, high reliability and efficiency. This increases continuously the demands of advancement in the GPU. The development of GPUs is benefited from the development of micro-controllers and power semiconductors. With enormous computational power, digital control units are becoming much faster, more advanced and low price. GPUs have a need for great computational power, because of the 400 Hz fundamental frequency and the increasing demands of the GPUs. The high fundamental frequency results in a low ratio between the switching frequency (2-10 kHz in the present power range) of the converter and the fundamental output frequency (400 Hz). Existing systems have been equipped with optimized modulation schemes like sine pulse width modulation and equal pulse width modulation scheme, which minimize the harmonic distortion. Thus, the need for filtering is reduced and smaller filter components are sufficient.

3. MATRIX CONVERTER FOR AGPU

Figure 1 shows the block diagram of the SPMC. The frequency of the input voltage is modulated in the SPMC. Thus, the output voltage is obtained with a step-changed frequency and variable amplitude. The LC input filter is required to reduce the switching ripple in an input current. Figure 2 shows the matlab simulation circuit of the SPMC. It uses four bi-directional switches to serve as an SPMC. This arrangement has the advantage of an independent control of the current in both directions. Since these bidirectional switches are not available at present, they are substituted with two diodes and two IGBT's, connected anti-parallel.

IGBTs are used because of their high switching capabilities and high current carrying capabilities, leading to high power applications. Diodes are included to provide the reverse voltage blocking capability.

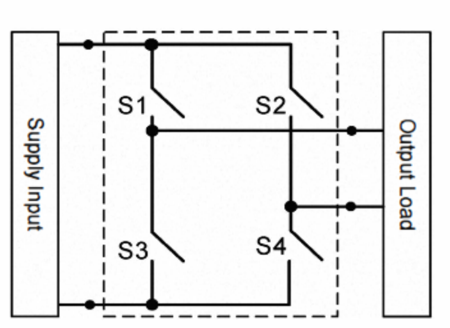

Figure 1. Block diagram of SPMC

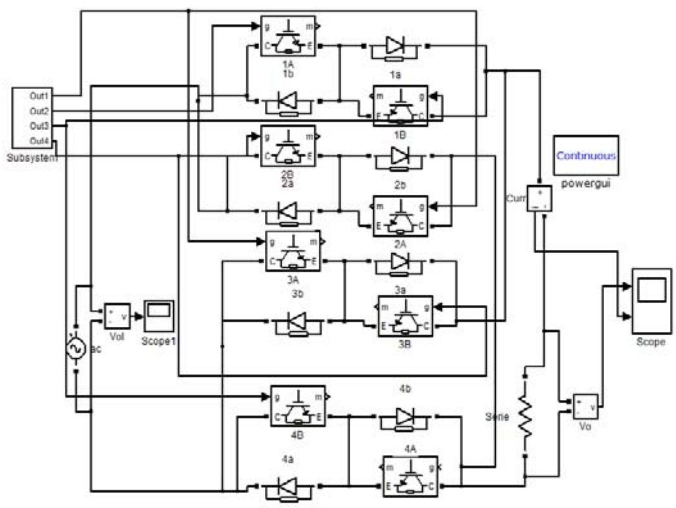

Figure 2. Matlab simulation Circuit diagram of Single Phase Matrix Converter

Implementing this SPMC requires different switching arrangements based on the desired amplitude and frequency. The amplitude of the output voltage is controlled by varying the modulation index of the sine/equal PWM pulses, and the frequency of the output voltage depends on the switching strategy. Furthermore, if inductive loads are used, a change in instantaneous current across the inductance will produce large voltage spikes, that will destroy switches in use, due to stress. A systematic switching sequence is thus required, that allows for the energy flowing in the IGBTs to dissipate within the system. In this paper, the frequency of the input voltage is taken as 50Hz, and the desired output frequency is assumed to be 400Hz. The switching strategies for this desired output frequency is given further in detail for better understanding.

4. SWITCHING STRATEGY

The operation of the SPMC can be explained in four modes as shown in figure 3. The desired output frequency is then synthesized by the proper sequencing of these four modes.

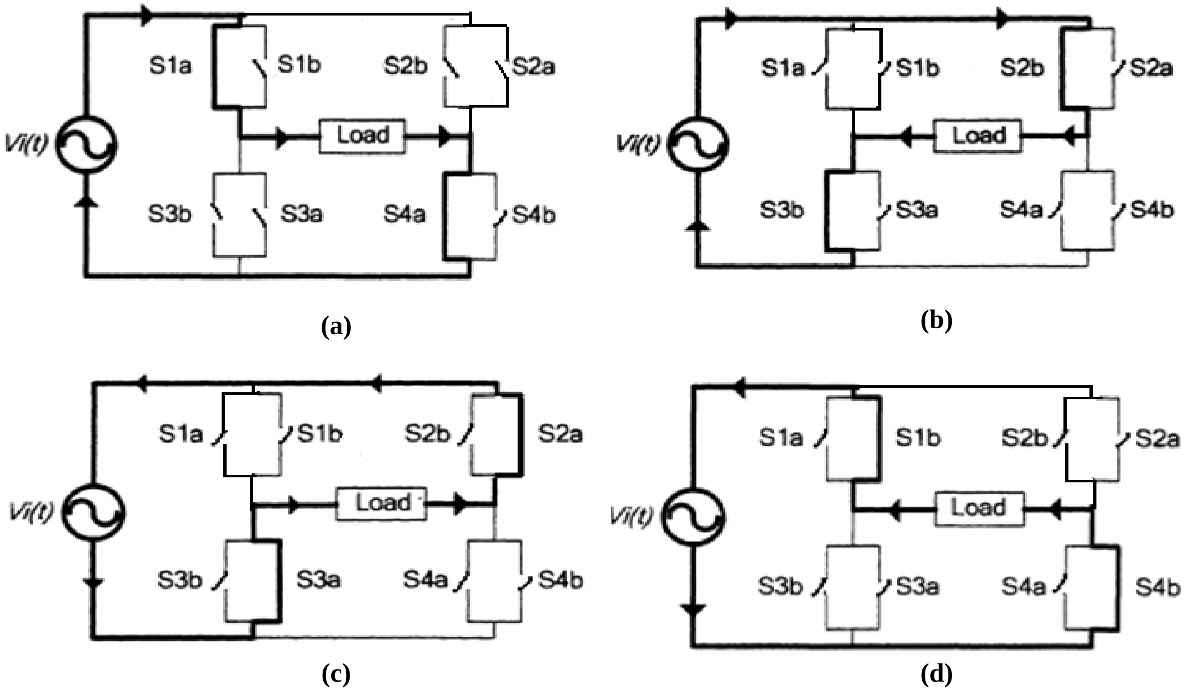

Figure 3. Equivalent Circuits for (a) Mode-1, (b) Mode-2, (c) Mode-3, (d) Mode-4

The sequence of the switching control for an output frequency of 400Hz without safe commutation is given in Table 1.

Table 1. Sequence of Switching Control

Input frequency	Output frequency	Mode	Switches on
50Hz	400Hz	1	S1a & S4a
		2	S2b & S3b
		1	S1a & S4a
		2	S2b & S3b
		1	S1a & S4a
		2	S2b & S3b
		1	S1a & S4a
		2	S2b & S3b
		3	S2a & S3a
		4	S1b & S4b
		3	S2a & S3a
		4	S1b & S4b
		3	S2a & S3a
		4	S1b & S4b
		3	S2a & S3a
		4	S1b & S4b

To generate sinusoidal PWM signals for the switches of the matrix converter, a model is developed, and the same is shown as a separate subsystem in Figure 4.The state selector signal portion implements the operation of the required switching state of Table 1. Here, the square wave pulse represents the desired output frequency, which is generated by the "pulse generator" block. The final switching pattern for the SPMC is produced, by multiplying the output from the SPWM generator with the state selector signal, using the "multiply" block. Each output from the "pulse generator" is multiplied with both outputs from the SPWM.

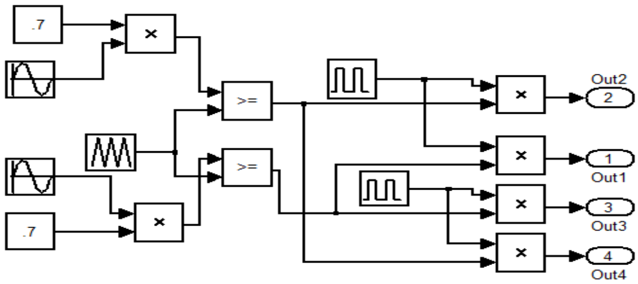

Figure 4. Four subsystems to generate Sine PWM pulses

5. RESULTS AND DISCUSSIONS

The simulation results of the SPMC for R and RL Loads without and with safe commutation strategy is discussed below.

5.1. Simulation Results of the SPMC for R Load

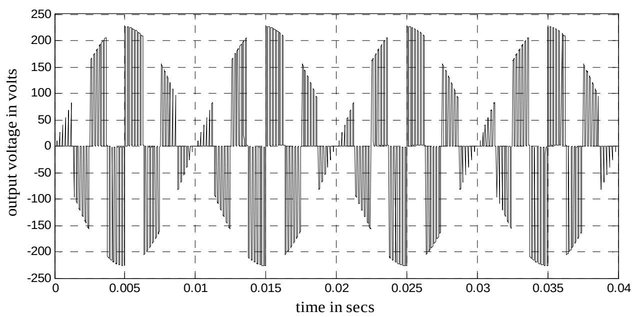

Figure 5. Output voltage for R Load: 400 Hz

5.2. Simulation Results of the SPMC for RL Load without safe commutation

The single phase matrix converter for RL load without safe commutation delivers an output voltage as shown in the waveform below in the figure.6 for 400 Hz consist of spike with magnitude up to ten times higher than the normal output voltage which needs to be eliminated by following a safe commutation technique without engaging a separate snubber circuit.

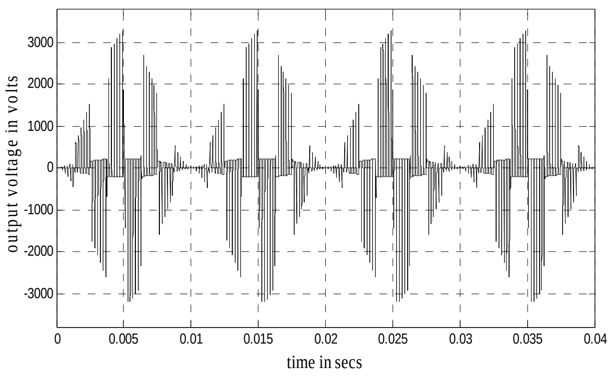

Figure 6. Output voltage of RL Load without safe commutation strategy: 400 Hz

5.3. Simulation Results of open loop simulink model with disturbance in AGPU

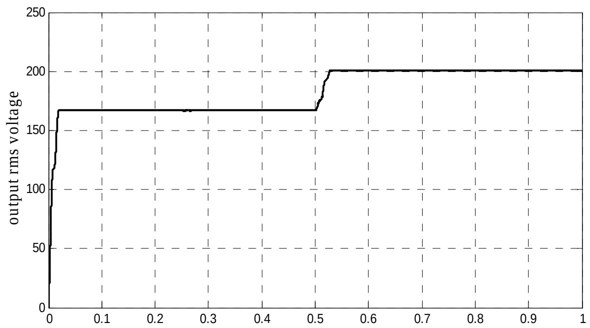

Figure 7. Output voltage waveform of open loop with disturbance

5.4. Simulation Results of closed loop simulink model with disturbance in AGPU

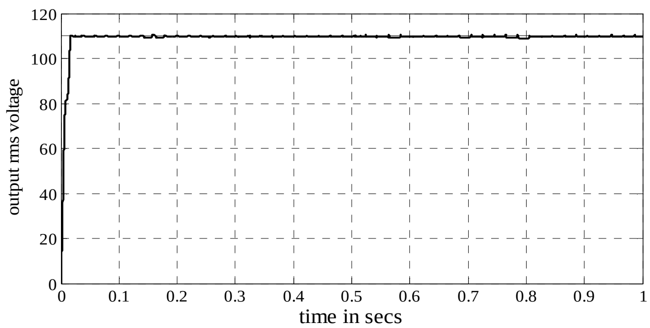

Figure 8. Output voltage waveform of closed loop with disturbance

6. CONCLUSION

Thus the output voltage waveform shown in figure.8 is suitable for the avionics use due to its consistency even during the distortions. Also the output voltage rms with a magnitude of 110V/400Hz is obtained to supply the airplanes during stopovers at the airports. The Single Phase Matrix Converter, with Sinusoidal pulse width modulation switching techniques, has been used with for R and RL loads. The spikes generated in the output voltage during switch transitions, are reduced with a safe commutation strategy, which provides a continuous current path in dead time, without a snubber circuit. The simulation using this simple PI control structure is carried out, to verify the consistency of the output voltage. Also, the proposed structure provides a compact solution with no DC link.

REFERENCES

[1] L.Gyugyi and B.R.Pelly, *Static Power Frequency Changers: Theory, Performance and Application*. New York: Wiley, 1976.

[2] Nithin T Abraham, K Vinoth Kumar, Vicky jose, Dona maria Mathew, S.suresh kumar, "*SAR Algorithm Method in Photovoltaic Systems Using MPPT*", in International journal of Power electronics and drives systems (IJPEDS), Vol 3,no 4, December 2013, pp:438-443.

[3] M.Venturini and A.Alesina, *"The generalized transformer: A new bidirectional sinusoidal waveform frequency converter with continuously adjustable input power factor," in Proc. IEEE PESC 1980*, pp. 242-252.

[4] A.Zuckerberger, D.Weinstock and A.Alexandrovitz, *"Single-phase matrix converter,"* in Proc. Inst. Electrical Engineering Electric Power Application, 1997, Vol. 144, pp. 235-240.

[5] Uffe Borup Jensen, Morten Peter Rasmussen,,Tonny Mortensen. *"A New Control Method for 400 Hz Ground Power Units for Airplanes"*, IEEE 1998, pp. 464-470.

[6] R.Baharom, Hasim M.K.Hamzah, Omar, *"A new single-phase controlled rectifier using SPMC,"* IEEE PECon 2006, pp. 453-458.

[7] Kwon, B.-H., Min, B.-D., Kim, J.-H., *"Novel Commutation Technique of AC-AC Converters,"* Electric Power Application, (e) EE Proceedings-, Vol. 145 (4), July 1998, pp. 295-300.

BIOGRAPHIES OF AUTHORS

Nithin T.Abraham received his B.Tech. degree in Electrical and Electronics Engineering from Karunya University, Coimbatore, Tamil Nadu, India. Presently he is pursuing M.Tech in Renewable Energy Technologies from Karunya University, Coimbatore, Tamil Nadu, India. His present research interests are Neural Networks and Fuzzy Logic, Special machines, Application of Soft Computing Technique, Solar PV based power generation.

C.A Pradeep Kumar received his B.Tech. degree in Electrical and Electronics Engineering from park college of engineering and technology, Coimbatore, Tamil Nadu, India. Presently he is pursuing M.Tech in Renewable Energy Technologies from Karunya University, Coimbatore, Tamil Nadu, India. His present research interests are Application of Soft Computing Technique, Hybrid vehicles, Renewable energy.

Shaema Lizbeth Mathew received her engineering degree in Electrical and Electronics from Federal Institute of Science and Technology (FISAT), Ernakulam in 2011. She is pursuing her master's degree in Renewable Energy Technologies from Karunya University, Coimbatore. Her field of interest concerns the photovoltaic power and MATLAB coding.