Experimental Verification of Isolated DC-AC Converter with Matrix Converter using Pulse Density Modulation Method

Ryo Oshima* Hiroki Takahashi* Jun-ichi Itoh*

*Nagaoka University of Technology

Abstract:- This paper verifies an isolated DC-AC power converter using a single phase to three phase matrix converter in experiments. The matrix converter does not require large reactors and large smoothing capacitors in the DC-link part. Furthermore, the proposed control method enables zero voltage switching (ZVS) by implementing the phase shift control on the inverter and the pulse density modulation (PDM) on the matrix converter. In this paper, the fundamental operation of the converter is confirmed by experimental results. From the experimental results, the total harmonic distortion (THD) of the output voltage is 7.53%.

Keywords : DC-AC converter, Matrix converter, Pulse density modulation, Zero voltage switching

1. Introduction

Recently, battery energy storage systems actively have spread and need a DC-AC converter for connecting the grid and battery. Such converters need to be isolated by a transformer in order to protect from failure and noises. However, the transformer of commercial frequency is large and heavy. In consequence, a high frequency AC link converter has been researched for down-sizing the transformer [1]-[2].

The authors have proposed an isolated DC-AC converter which adopts the matrix converter using the pulse density modulation in order to improve the efficiency [3]. This proposed circuit achieves ZVS by using the pulse density modulation.

This paper provides the fundamental operation of the proposed circuit with no load experiment under the condition of the input DC voltage of 200 V and AC link frequency of 50 kHz. From the results, it is confirmed that the output voltage THD is obtained to 7.53% and ZVS can be achieved on the matrix converter at the secondary side of the transformer.

2. Circuit configuration

Fig. 1 shows the main circuit configuration of the proposed DC-AC converter with the matrix converter using the pulse density modulation method. This circuit is divided into a full bridge inverter by a phase shift control at the primary side of the transformer and the matrix converter at the secondary side.

The proposed system achieves high efficiency because the number of power conversion at secondary side of the transformer is once only due to the direct AC-AC conversion. In addition, the matrix converter promises to achieve long lifetime and to reduce the volume of the DC-AC converter because the bulky DC-link capacitors and an initial charge circuit are not required. However, it is difficult to reduce the switching loss when the pulse width modulation (PDM) is applied to the matrix converter.

Therefore, in the proposed system, the zero voltage periods are generated by the primary inverter with phase-shift control in order to achieve ZVS in the matrix converter. Then, the output voltage of the matrix converter is generated by PDM at the zero voltage period.

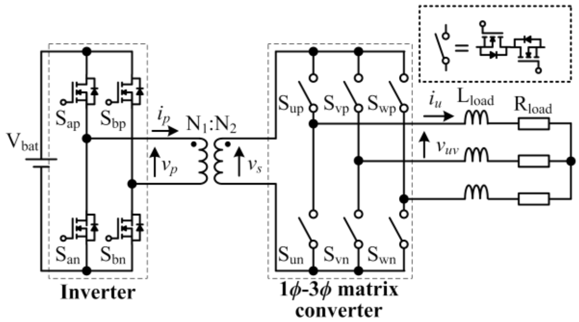

Fig.1. DC-AC converter with the matrix converter.

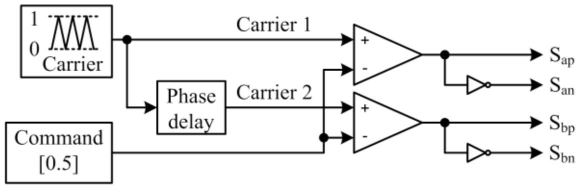

Fig.2. Control block diagram of the inverter.

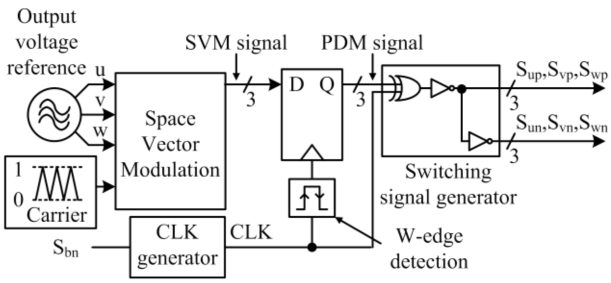

Fig.3. Control block diagram of the matrix converter.

3. Control Strategies

3.1 Phase shift control Fig. 2 shows a control block diagram of the phase shift control for the inverter. The inverter outputs 3-level voltage which includes zero voltage by the phase shift control. Therefore, the matrix converter achieves ZVS when the matrix converter turns at the zero voltage period provided by the inverter.

3.2 Pulse density modulation method based on space vector modulation [4] Fig. 3 and Fig. 4 shows a control block diagram and the operation waveforms of the pulse density modulation which enables ZVS of the matrix converter. The PDM controls the density and the pole of the constant width pulse, and then these pulse signals are used as the minimum unit of the output voltage waveform. The input voltage of the matrix converter consists of the high frequency square waveform because the inverter outputs square waveform to the matrix converter with the phase shift control. Therefore, a half cycle of the input voltage is used as 1 pulse of the PDM. Then, in order to yield the gate signals by the PDM, the control block diagram includes a D type flip-flop to quantize the duty references generated by a space vector modulation (SVM). The clock (CLK) to drive the D type flip-flop is synchronized with the zero voltage period owing to the phase shift control. As a result, the PDM and the ZVS of the matrix converter are implemented.

4. Experimental Results

Table 1 shows the experimental conditions. The experiments of the proposed system are implemented in order to confirm the fundamental operation and the ZVS.

Fig. 5 shows the input and output waveforms of the matrix converter. It should be noted that the cut-off frequency of the low pass filter for the output voltage is 1 kHz. The filtered output voltage is sinusoidal and the output voltage THD is obtained to 7.53%. Therefore, the proposed system can be connected to the grid if the interconnection inductors are set to several percent of the rated power capacity.

Fig. 6 shows the enlarged waveform of Fig. 5. From the secondary voltage waveform of the transformer, the 50-kHz and 3-level voltage which has the zero voltage periods is confirmed. In addition, the output voltage waveform consists of the secondary voltage pluses of the transformer and the density of the pulses are controlled by the PDM. Thus, the PDM of the matrix converter is confirmed.

Fig. 7 shows the ZVS operation of the matrix converter in the proposed system. From the results, when the secondary voltage of the transformer is in a zero voltage period, the switching of the matrix converter is implemented and the ZVS is achieved.

5. Conclusion

This paper verifies an isolated DC-AC converter using a matrix converter experimentally. The matrix converter in the proposed system is applied the PDM and achieves ZVS by combination with the high frequency inverter with the phase shift control. From the experimental results, the ZVS operation and the PDM of the matrix converter are confirmed in the experiment with no load. Moreover, the output voltage THD of 7.53% is obtained. Therefore, the validity of the proposed system is confirmed.

In the future work, the load characteristics, efficiency and performance of the proposed circuit will be evaluated in experiments.

References

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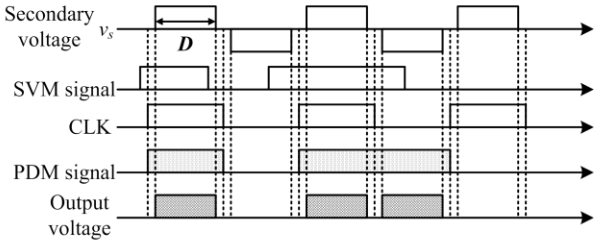

Fig.4. Operation principle of the pulse density modulation for the matrix converter.

Table 1. Experimental conditions.

Battery voltage	V_{bat}	200 V
Carrior frequency of inverter	f_{c_inv}	50 kHz
Carrior frequency of matrix converter	f_{c_mc}	5 kHz
Modulation frequency of matrix converter	f_{m_mc}	50 Hz
Turn ratio	N_1:N_2	1:2
Duty of primary voltage	D	0.75 p.u.

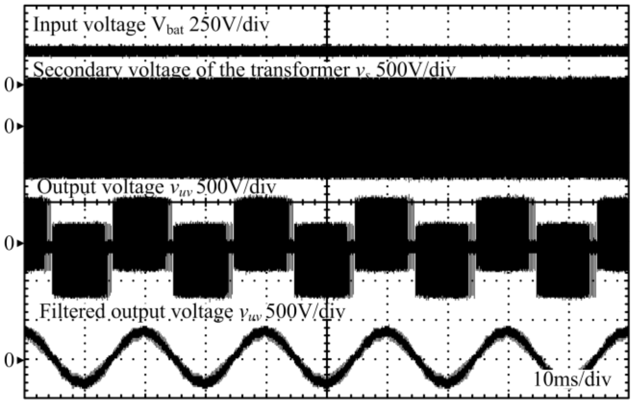

Fig.5. Experimental waveforms of the secondary voltage of the transformer and output voltage of the DC-AC converter with no load.

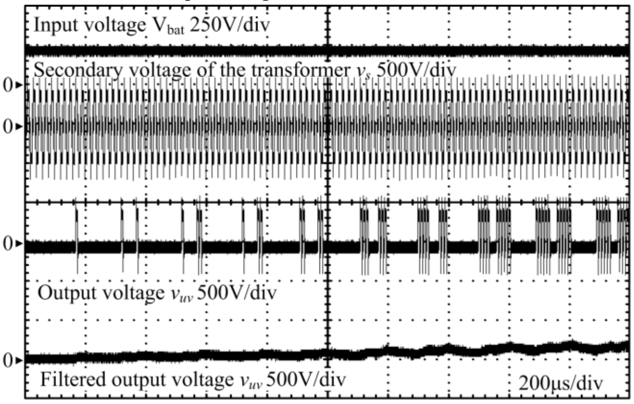

Fig.6. Enlarged waveforms of Fig.5

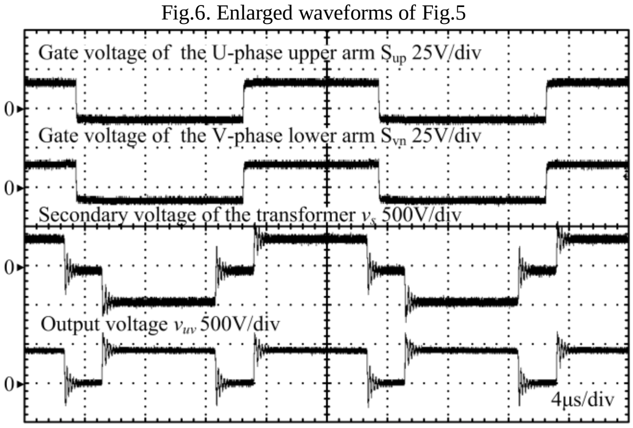

Fig.7. Experimental waveforms when the gate signals are turned in the zero voltage period.