Characteristics of Non-Isolated OSAKA Converter

-Characteristics of Three-Phase Soft-Switching Power Factor Corrected Converter

for Large Scale Power Without Three-Phase Transformer-

Katsunori Taniguchi, Wataru Shimomori
Osaka Institute of Technology
Hyun Woo Lee
Kyungnam University

Non-isolated OSAKA Converter, which removes a three-phase transformer, is described in this paper. The converter switches once in every half cycle of an AC commercial power source. Therefore, it can solve many problems caused by the high frequency operation. The proposed converter achieves the soft-switching operation and the EMI noise can be reduced. In this circuit, the resonant capacitor, which is used for the soft-switching operation, is utilized for the improvement of an input current waveform. To achieve low cost and compact structure, non-isolated OSAKA converter removes a three-phase transformer of the OSAKA converter. By removing the three-phase transformer, three phase currents occur the interferences each other. To avoid the interference, a new switching method for non-isolated OSAKA converter is proposed. The converter can be constructed by the low-speed large power devices. The converter generates the low distorted input current waveforms with high power factor.

Keywords : Three-Phase PFC, Converter, Single-Pulse, Soft-Switching, Large Scale

1. Introduction

PWM rectifiers require the high frequency operation causing the many problem such as switching losses, high stress of switching devices, EMI noise, high cost of devices, etc.. Moreover, the control scheme of the PWM rectifier is more complex and the cost of the circuit configuration is higher. For large-scale converter such as mega watts power, it is important to go back to the basics of the converter and to design a simple control scheme.

Large-scale three-phase soft-switching power factor corrected converter so called "OSAKA converter" has been proposed[1]. The switching device of the OSAKA converter switches once in every half cycle of an AC commercial power source. Therefore, it can solve many problems caused by the high frequency operation. Low switching frequency, simple control scheme of the system and simple circuit configuration satisfy the condition to construct the large-scale converter. However, the higher switching power generates the higher electromagnetic interference (EMI) even if the switching frequency is very low. Soft-switching techniques are generally used to reduce the electromagnetic interference. The proposed OSAKA converter achieves the soft-switching operation and then EMI noise in the large-scale converter can be reduced. The resonant capacitor, which is used for soft-switching operation, is also utilized for the improvement of an input current waveform.

In this paper, a non-isolated OSAKA converter is proposed. To achieve low cost and compact structure, non-isolated OSAKA converter removes a three-phase transformer of the OSAKA converter. By removing the three-phase transformer, three phase currents occur the interferences each other. To avoid the interference, a new switching method for non-isolated OSAKA converter is

proposed.

2. Single-Pulse Soft-Switching (SPSS) PFC Converter

To improve the input current waveform, we have proposed a SPSS (Single-Pulse Soft-Switching) PFC converter as shown in Fig.5[2], [3], [4]. A soft-switching circuit consists of a series connected switch-diode pair (T_{r1} - D_{r2} , D_{r1} - T_{r2}) with resonant capacitor C_r . The switching devices (T_{r1} and T_{r2}) of a SPSS converter switches once in every half cycle of an AC commercial power source. When the switching devices, T_{r1} and T_{r2}, are turned off simultaneously, the inductor current charges the capacitor C_r in the soft-switching circuit. Then, turn-off of T_{r1} and T_{r2} is the ZVS (Zero Voltage Switching). Since the input current
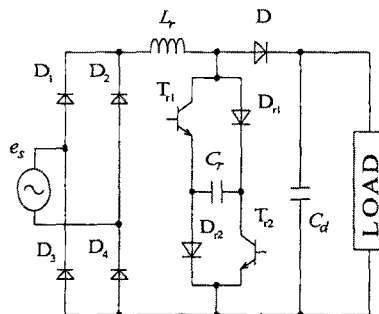

Fig.1 Single-Pulse Soft-Switching PFC converter.

of the SPSS-PFC converter always begin at zero, turn-on of T_{r1} and T_{r2} is the ZCS (Zero Current Switching). Therefore, the proposed SPSS converter achieves the

soft-switching operation (ZCS at turn-on and ZVS at turn-off) and, the EMI noise and switching loss can be reduced. A charged voltage of resonant capacitor C_r at the end of switching operation is equal to a DC output voltage E_d.
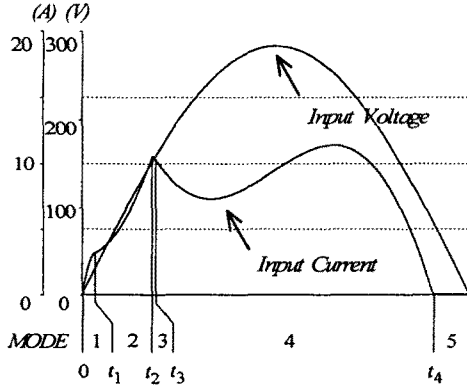

Fig.2 Waveforms of input voltage and input current of single-pulse soft-switching PFC converter

3. Non-Isolated OSAKA Converter

Fig.3 shows a circuit configuration of the proposing the non-isolated OSAKA converter. To achieve low cost and compact structure, non-isolated OSAKA converter removes a three-phase transformer of the OSAKA converter[5]. By removing the three-phase transformer, three phase currents occur the interferences each other. To avoid the interference, a new switching method for non-isolated OSAKA converter is proposed.

Fig. 4 shows the several voltage and current waveforms of the converter to obtain a three-phase sinusoidal current waveforms with high power factor. In Fig.3, three-phase currents are given by

$$i_u = i_{uv} - i_{wu} \qquad (14)$$
$$i_v = i_{vw} - i_{uv} \qquad (15)$$
$$i_w = i_{wu} - i_{vw} \qquad (16)$$

The currents ($i_{uv}^*, i_{vw}^*, i_{wu}^*$) shown in Fig. 4 are waveforms of inductor currents which three-phase currents become sinusoidal wave with unity power factor. In the half cycle of i_{uv}^*, 60° interval of i_{uv}^* from 30° to 90° of v_{uv} is same waveform to e_u^*, and 60° interval of i_{uv}^* from
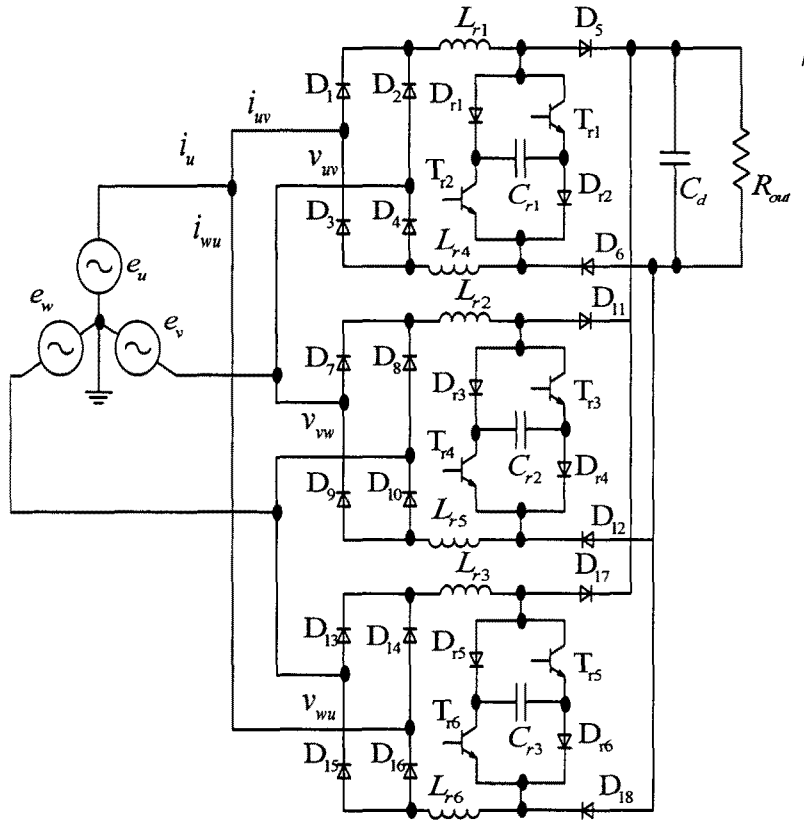

Fig.3 Circuit configuration of proposed   non-isolated OSAKA converter.
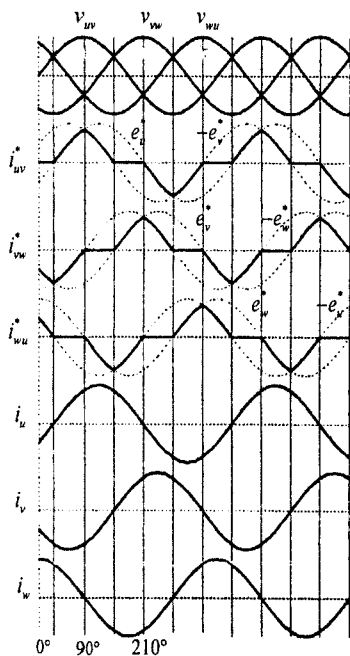
Fig.4 Several voltage and current waveforms of
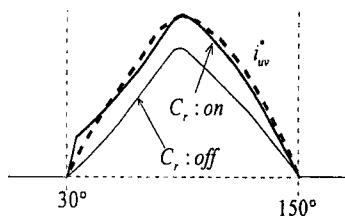Proposed non-isolated OSAKA converter.

Fig.5 Approximation of inductor current waveform.

Table 1 Principal Parameters of non-isolated
OSAKA converter.

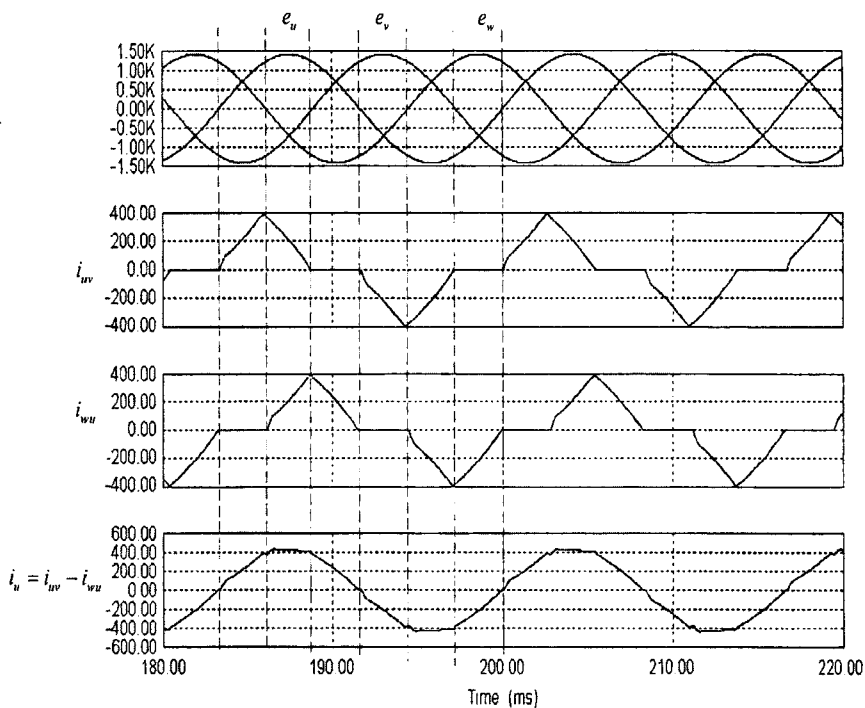| Source Voltage	E_s	$1000\sqrt{2}$ V
Inductor	L_r	8 mH
Capacitor	C_r	6μF
On interval	T_{ON}	2.55 ms
Capacitor	C_d	1000μF
Load	R_{out}	20Ω

Fig. 6 Simulated voltage and current waveforms of the non-isolated Osaka converter.

90° to 120° of v_{uv} is same waveform to $-e_v^*$. Similarly, waveforms of i_{wv}^* and i_{wu}^* can be also obtained by same manner.

A dotted line shown in the Fig.5 is the inductor current waveform in order to obtain a sinusoidal phase-current. Therefore, the three-phase currents can be improved if the inductor current waveforms of the non-isolated OSAKA converter can be approximated to the waveform of dotted line shown in the Fig.5. $C_r : off$ is the case removing the resonant capacitor and means a hard switching operation of the non-isolated OSAKA converter. The hard switching operation increases distortion of three-phase currents because the inductor current of $C_r : off$ is not able to obtain a closing waveform to the dotted line in the Fig.5. The Non-Isolated OSAKA converter is also suitable for large-scale system because the proposed converter can be constructed by the low-speed large power devices, achieves the soft-switching operation and generates the low distorted input current waveform with high power factor.

Fig.7 shows a relation between ON time duration of switching devices and DC output voltage in accordance with DC output power. DC output power is proportional to ON time duration and DC output voltage can be kept almost constant values.

Fig.8 shows THD and Power Factor vs ON time duration of switching devices. THD is smaller than 5.5% and power factor is larger than 99%.
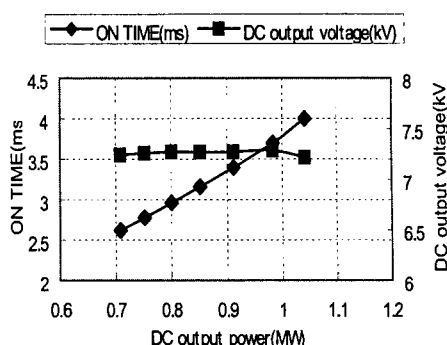

Fig.7 relation between ON and DC output voltage in accordance with DC output power

Fig.8 THD and Power Factor vs ON time duration of switching devices

4. Conclusions

OSAKA converter is a large-scale three-phase soft-switching power factor corrected converter. The converter switches once in every half cycle of an AC commercial power source. Therefore, it can solve many problems caused by the high frequency operation. The higher switching power generates the higher EMI even if the switching frequency is very low. The proposed converter reduces the EMI due to achieve the soft-switching operation. In this circuit, resonant capacitor, which is used for soft-switching operation, is also utilized for the improvement of an input current waveform.

In the OSAKA converter, three-phase transformer is employed due to cancel the third harmonic components included in the input phase currents. Non-Isolated OSAKA converter, which is a large-scale three-phase soft-switching power factor corrected converter without isolation, has been a three-phase transformer of the OSAKA converter. By proposed in this paper. To achieve low cost and compact structure, non-isolated OSAKA converter removes removing the three-phase transformer, three phase currents occur the interferences each other. To avoid the interference, a new switching method for non-isolated OSAKA converter is proposed. The proposed circuit is very simple. The Non-Isolated OSAKA converter is also suitable for large-scale system because the proposed converter can be constructed by the low-speed large power devices, achieves the soft-switching operation and generates the low distorted input current waveform with high power factor.
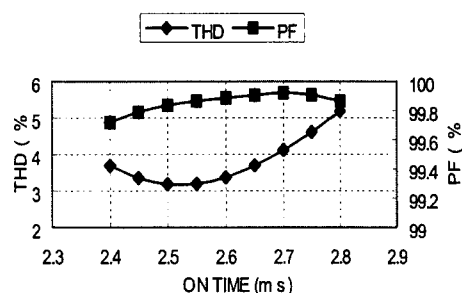
References

(1) Taniguchi, "Proposition of the OSAKA Converter" - OSAKA Converter: Large Scale Three-Phase Soft-Switching Power Factor Corrected Converter – ICPE'04, pp. I -26 - I -30, (2004)

(2) Taniguchi, Watanabe, "Single Pulse Soft- Switching PFC Converter", 1999 National Convention Record IEEJ, 856, (1999)

(3) Taniguchi, Watanabe, Morizane, Kimura "Characteristics of, Single-Pulse Soft-Switching PFC Converter" IEEE IES, IEEE IECON 2000, Proceedings, pp. 2648/2653 (2000/ 10)

(4) Taniguchi, Baba, Ogawa, Kawaji: "Driving Circuit for Single-Pulse Soft-Switching PFC Converter" PCC-OSAKA'2002 pp.1232-1237, (2002/4)

(5) Nagai, Shimada, Ito, Nakamura "Three-Phase PFC Converter using Single-Phase Choppers without Isolation Transformer", 1998 National Convention Record IEE Japan, 762, (1998/3)