

# Selective Dual Utility AC Voltage Link Soft-Switching PWM Controlled DC-DC Power Converter with High Frequency Transformer for 36V-350A DC Loads

Keiki Morimoto

Toshimitsu Doi

Haruhiko Manabe

Daihen Corporation, Osaka, Japan  
morimoto-k@daihen.co.jp

Nabil A. Ahmed

Hyun-Woo Lee

Mutsuo Nakaoka

Kyungnam University, Korea  
nabil@acc.aun.edu.eg

Tarek Ahmed

Yamaguchi University, Japan  
tarek@pe-news1.eee.yamaguchi-u.ac.jp

**Abstract**—This paper presents two new circuit topologies of DC busline series active snubber assisted soft-switching PWM full-bridge DC-DC power converter acceptable for either utility AC 200V-rms or AC 400V-rms input voltage source. One of proposed power converters is composed of a typical voltage source full-bridge high frequency PWM inverter using DC busline side series switching devices with the aid of a parallel capacitive lossless snubber. All the active power switches in the full-bridge arms and DC busline can achieve ZCS turn-on and ZVS turn-off commutation operation and consequently the total turn-off switching losses can be significantly reduced. As a result, a high switching frequency for used IGBTs can be actually realized more than about 20 kHz. It is proved that the more the switching frequency of full-bridge inverter increases, the more soft-switching PWM DC-DC power converter with a high frequency transformer link has remarkable advantages for its power conversion efficiency and power density as compared with the conventional hard-switching PWM inverter type DC-DC converter. The effectiveness of this new converter topology is proved for low voltage and large current DC-DC power supplies as arc welding machine from a practical point of view.

**Keywords:** DC-DC power converter, Voltage source full-bridge topology, High frequency transformer links, Soft-switching PWM, Active switch assisted lossless capacitive snubber, Arc welding power supply in industry

## I. INTRODUCTION

### A. Research Backgrounds

Recently, a saturable inductor assisted ZVS-PWM full-bridge high-frequency inverter link DC-DC power converter [1] and lossless capacitors and transformer parasitic inductive components assisted soft-switching DC-DC power converter with phase-shifted modulation control scheme in secondary-side of high frequency transformer [2]-[5] have been developed and evaluated so far. These power converter circuit topologies are suitable for handling high output power more than about several kW, especially for high voltage and low current applications as new energy related power supplies. However, secondary magnetic switches or transformer secondary side semiconductor switching devices in these converter circuit topologies may cause large conduction loss when these power circuit topologies are adopted for low voltage and large current application as arc welding power supplies. Therefore, for the low voltage and

large current application, a soft-switching DC-DC power converter with active switches in the primary side of the high frequency transformer is considered to be more suitable.

On the other hand, utility AC 200V-rms or AC 220V-rms is commonly used as the industrial utility AC power distribution power source in Japan, Korea and Taiwan. The other countries in the world, United States, Europe, China and so forth, AC 380V-rms, AC 400V-rms or AC 460V-rms utility power source are generally used as the industrial utility power distribution system. Thus, when we export the industrial products using inverter type DC-DC power converter with high frequency transformer designed for utility AC 200V-rms input line to the area where utility AC 400V-rms input line is used, the primary side circuit of high frequency transformer winding should be completely re-designed. This has been a problem to be solved and cost-consuming for designers and companies which try to sell their new products in the world wide markets.

### B. Research Objectives

This paper presents two novel circuit topologies of voltage source full-bridge type soft-switching PWM inverter suitable for either utility AC 200V-rms or AC 400V-rms input line, which are composed of typical H full-bridge inverter and additional semiconductor switching devices for DC busline PWM series switching with the aid of a lossless capacitive snubber. Under the newly-proposed soft-switching PWM full-bridge DC-DC power converter circuits with high frequency transformer, all the active switches in the full-bridge arms and DC busline can actively achieve ZVS/ZVT turn-off commutation operation.

The steady state operating principle of the soft-switching PWM full-bridge DC-DC power converters tested here is described, along with its remarkable features. The experimental operation results of those new type of soft-switching PWM full-bridge DC-DC power converters using IGBT power modules are illustrated including power loss analysis as compared with those of hard-switching PWM DC-DC power converter. The practical effectiveness of the proposed soft-switching PWM full-bridge DC-DC power converters acceptable and suitable for high power applications which are designed for low voltage and large current output is actually proved on the basis of experimental data.

## II. DC-DC CONVERTER FOR UTILITY AC 200V-RMS

### A. Circuit Description

Fig. 1 shows a high frequency transformer linked soft-switching PWM full-bridge DC-DC converter circuit for acceptable utility AC 200V-rms, which is composed of voltage source full-bridge inverter with active switches in series with the DC busline and a single lossless snubbing capacitor in parallel with the DC busline, a high frequency transformer with secondary side center-taped winding, DC reactor filter and DC load as arc welder. In the newly-developed DC-DC converter circuit, the active PWM switches; reverse conducting IGBT  $Q_5(S_5/D_5)$  and  $Q_6(S_6/D_6)$  in series with DC busline and a lossless capacitor in paralleled with DC busline are added in series with the DC power busline connected to the voltage source full-bridge high frequency inverter composed of  $Q_1(S_1/D_1)$ ,  $Q_2(S_2/D_2)$ ,  $Q_3(S_3/D_3)$  and  $Q_4(S_4/D_4)$ . In particular, a single lossless snubbing capacitor  $C$  is inserted between active switches  $Q_5$ ,  $Q_6$  and the full-bridge type inverter in order to achieve ZVS.

### B. Gate Pulse Timing Sequences

Fig. 2 depicts pattern sequences of switching gate driving pulses to be provided to the semiconductor switching devices; IGBTs.

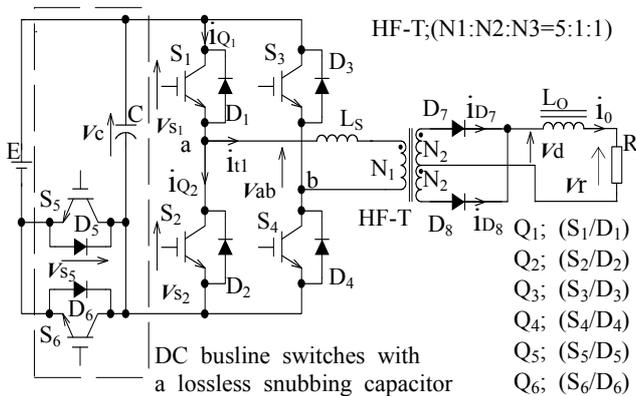


Fig. 1 The soft-switching PWM DC-DC power converter with high frequency transformer link for utility AC 200V-rms input

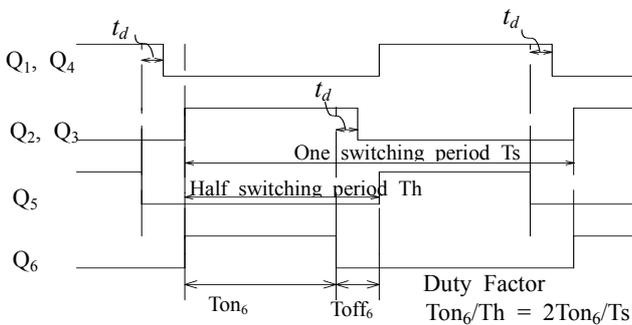


Fig. 2 Pattern sequences of switching gate driving pulses

The gate voltage pulse signals with a certain dead time, which are delivered to  $Q_1$  and  $Q_4$  or  $Q_2$  and  $Q_3$  in the voltage source full-bridge inverter arms, are the same as signal sequences of conventional full-bridge inverter. Regarding the turn-on gate pulse voltage signals to the DC busline side series switches  $Q_5$  or  $Q_6$ , the gate signals are applied to  $Q_5$  or  $Q_6$  at the same timing period as the turn-on gate pulse signals to  $Q_1$  and  $Q_4$  or  $Q_2$  and  $Q_3$ , respectively. As for the turn-off gate pulse voltage signals to  $Q_5$  or  $Q_6$ , the gate pulses are delivered to  $Q_5$  or  $Q_6$  before the predetermined specific length of time  $t_d$  on the basis of the time when the turn-off signals are respectively applied to the switches  $Q_1$  and  $Q_4$  or  $Q_2$  and  $Q_3$ .

### C. Circuit Operation Principle

Fig. 3 illustrates the relevant operating waveforms for the circuit with utility AC 200V-rms input in a complete switching period for the pulse pattern of gate drive timing sequences shown in Fig. 2. The operation modes of this converter circuit for the utility AC 200V-rms input are divided into seven operation modes from mode 0 to mode 6 in accordance with operation timing transitions from  $t_0$  to  $t_6$  and its operation principle is described in the following. The equivalent circuits corresponding to each mode are shown in Fig. 4.

**1) Mode 0 :  $\sim t_0$**  Before time  $t_0$ , the switches  $Q_1$ ,  $Q_4$  and  $Q_5$  are turned on. During this time, the primary side energy is supplied to the load  $R$  in the secondary circuit through the transformer HF-T.

**2) Mode 1 :  $t_0 \sim t_1$**  At time  $t = t_0$ , the series switch  $Q_5$  in DC busline side is turned off simultaneously. At this time, the series switch  $Q_5$  can turn off with ZVS because the current  $i_{S5}$  through  $Q_5$  is immediately cut off with the aid of the lossless snubbing capacitor  $C$ . After time  $t_0$ , the voltage  $v_C$  across the lossless snubbing capacitor  $C$  discharges toward zero voltage from  $E$ . Voltage.

During this time, the voltage  $v_C$  across the lossless snubber capacitor  $C$  can be estimated as,

$$v_C(t) = E - (i_{l1} / C) t \quad (1)$$

Where,  $i_{l1}$  is a primary current of high frequency transformer. From the eq. (1), the discharging time  $t_{dc}$  of the capacitor  $C$  until the voltage  $v_C$  becomes zero is given by,

$$t_{dc} = CE / i_{l1} \quad (2)$$

Under this newly-developed converter circuit, an appropriate delay time  $t_d$  indicated in Fig. 2 is designed so as to be a little longer than the time calculated from the eq. (2) under the condition of the maximum  $i_{l1}$  and the maximum output current. In this case, switches  $Q_1$  and  $Q_4$  or  $Q_2$  and  $Q_3$  can achieve ZVS transition completely. If we need to widen the complete ZVS operation range at the turn-off commutation for the switches  $Q_1$  and  $Q_4$  or  $Q_2$  and  $Q_3$ , the optimum delay time  $t_d$  should be varied according to the value of the transformer primary current  $i_{l1}$ .

**3) Mode 2 :  $t_1 \sim t_2$**  At time  $t = t_1$ , the voltage  $v_C$  is completely discharged to zero. In the interval from  $t_1$  to  $t_2$ ,

the diodes  $D_2$  of  $Q_2$  and  $D_3$  of  $Q_3$  are turned on and the current  $i_{i1}$  through the transformer primary winding flows through the two circulation loops;  $L_S \rightarrow D_3 \rightarrow S_1 \rightarrow L_S$  and  $L_S \rightarrow S_4 \rightarrow D_2 \rightarrow L_S$ .

**4) Mode 3 :  $t_2 \sim t_3$**  At time  $t = t_2$ , the switches  $Q_1$  and  $Q_4$  are turned-off. At this time, because the voltage  $v_C$  across the lossless snubbing quasi-resonant capacitor has been already equal to zero and the diodes  $D_2$  of  $Q_2$  and  $D_3$  of  $Q_3$  immediately turn on, the active switches  $Q_1$  and  $Q_4$  can be turned off with ZVS.

At this mode, the condition that the capacitor  $C$  has been just charged up to the same voltage as DC busline voltage  $E$  can be estimated by eq. (3).

$$(1/2)CE^2 = (1/2)L_S(i_{i1})^2 \quad (3)$$

However, as described after, in mode 6, the circuit parameters should be designed to meet the condition of  $(1/2)CE^2 \leq (1/2)L_S(i_{i1})^2$  in order to achieve ZVS commutation at turn-on transition of the switch  $Q_6$ .

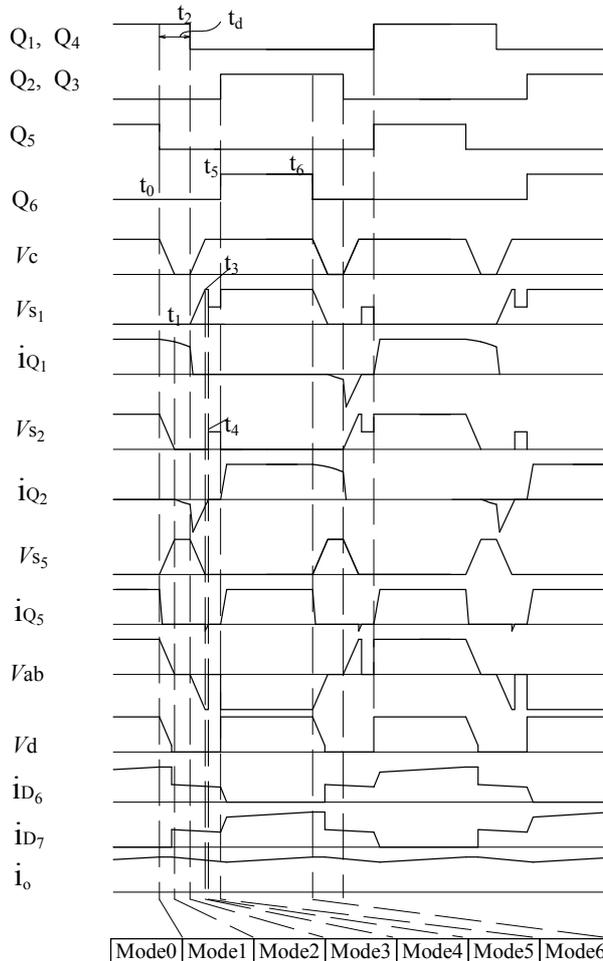
**5) Mode 4 :  $t_3 \sim t_4$**  Under a condition of  $(1/2)CE^2 < (1/2)L_S(i_{i1})^2$ , the voltage  $v_C$  across the snubber capacitor  $C$  is

clamped to DC busline voltage  $E$  after the voltage  $v_C$  reaches the DC busline voltage  $E$ , because the diodes  $D_5$  of  $Q_5$  and  $D_6$  of  $Q_6$  are turned on and the energy stored into leakage inductance  $L_S$  is returned back to the DC busline voltage source  $E$ .

**6) Mode 5 :  $t_4 \sim t_5$**  In this mode, all the operations are stopped in the primary circuit of high frequency transformer, except the voltages across the switches  $Q_1$  and  $Q_4$  decrease down to  $(1/2)E$  and the voltages across the switches  $Q_2$  and  $Q_3$  increase up to  $(1/2)E$  due to parasitic parameters of the switches  $Q_1, Q_2, Q_3$  and  $Q_4$ .

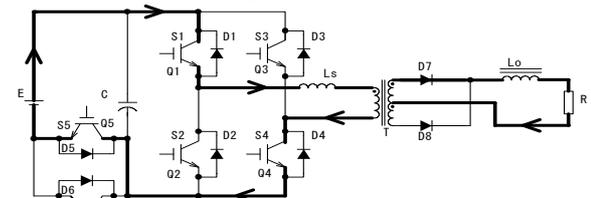
**7) Mode 6 :  $t_5 \sim t_6$**  At time  $t = t_5$ , the switches  $Q_2, Q_3$  and  $Q_6$  are turned on respectively. At this time, the switches  $Q_2, Q_3$  can be turned on with ZCS because of parasitic inductance  $L_S$  of the high frequency transformer. And more, the switch  $Q_6$  achieves ZVS/ZCS at a turn-on transition commutation because the voltage  $v_C$  is the same as DC power busline voltage.

Thereafter, the aforementioned operating processes are repeated in sequence during each switching cycle.

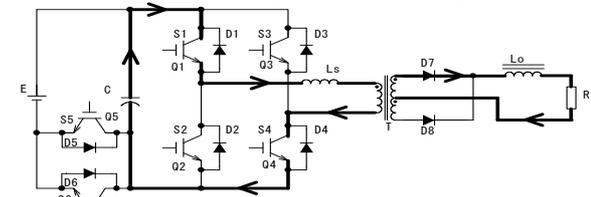


**Fig. 3** Operating waveforms of the circuit for AC 200V-rms input during one switching period

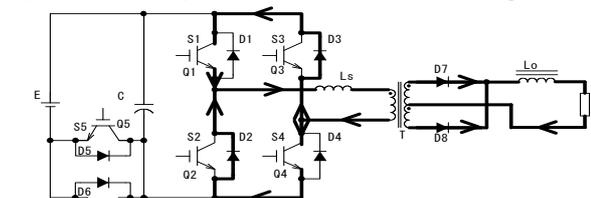
**(a) Mode 0 (  $\sim t_0$  ); Energy transfer to secondary during turn-on of  $Q_1, Q_4$  and  $Q_5$**



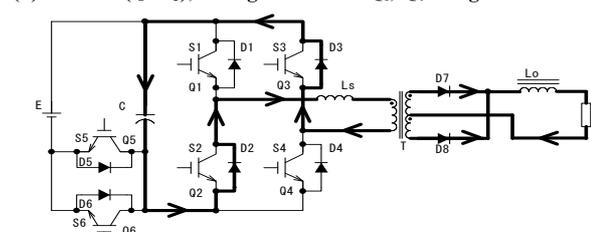
**(b) Mode 1 (  $t_0 \sim t_1$  ); Discharge of  $C$  after  $Q_5$  being turned off**



**(c) Mode 2 (  $t_1 \sim t_2$  ); Current circulation after discharge of  $C$**



**(d) Mode 3 (  $t_2 \sim t_3$  ); Charge of  $C$  after  $Q_1, Q_4$  being turned off**



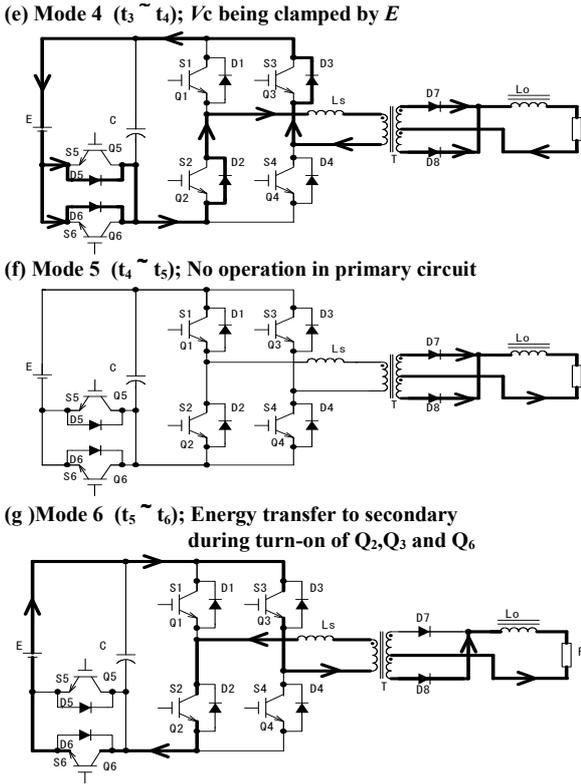


Fig. 4 Equivalent circuits for seven operational modes in case of utility AC 200V input

### III. DC-DC CONVERTER UTILITY AC 400V-RMS

#### A. Circuit Description

Fig. 5 shows a high frequency transformer linked soft-switching PWM DC-DC power converter topology acceptable for utility AC 400V-rms input. Under the DC-DC power converter circuit used for utility AC 400V input, the DC busline voltage source is selected by divided voltage sources  $E_1$  or  $E_2$ . The voltages  $E_1$  and  $E_2$  are designed so as to be equal to  $E$ . The switch  $Q_5$  in Fig. 1 is moved to the high side of DC busline in Fig. 5. The diodes  $D_9$  and  $D_{10}$  in series are also inserted in parallel with the DC busline between  $Q_5$  or  $Q_6$  and full-bridge inverter arms. And the center point between  $E_1$  and  $E_2$  is directly connected to the mid point between the diodes  $D_9$  and  $D_{10}$ .

#### B. Gate Pulse Timing Sequences and Operating principle

The timing pattern sequences of switching gate driving pulses for utility AC 400V-rms input are exactly the same as that for the utility AC200V-rms input shown in Fig. 2.

Under the newly-developed DC-DC converter suitable for the utility AC 400V-rms input, when the switches  $Q_5$  or  $Q_6$  are turned on and off alternately, half voltage  $E$  of DC busline voltage  $2E$  is applied to the lossless snubbing capacitor  $C$  and full-bridge inverter arms. Therefore, the same IGBTs rating as IGBTs in the converter circuit for utility AC 200V-rms input can be used even in the circuit for the utility AC 400V-rms input.

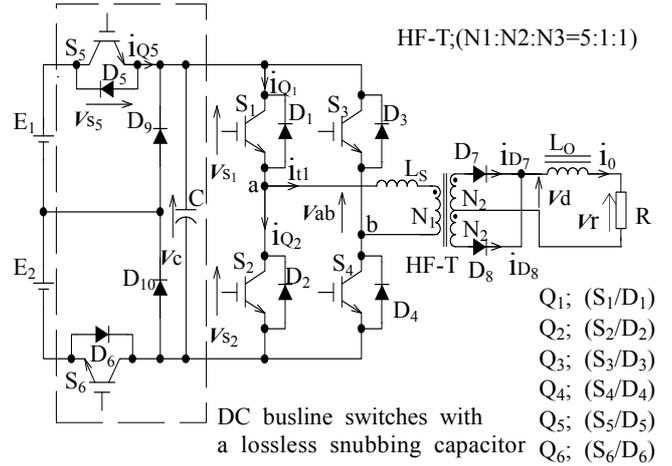


Fig. 5 The soft-switching PWM DC-DC power converter with a high frequency transformer link for utility AC 400V-rms input

In addition to this feature, when the switches  $Q_1$ ,  $Q_4$  and  $Q_5$  or  $Q_2$ ,  $Q_3$  and  $Q_6$  are turned on and turned off alternately at the same timing pulses as those for the switches in the DC-DC converter employed for the utility AC 200V-rms input shown in Fig. 1, all the switches can perform ZVS turn-off and perform ZCS or ZVS/ZCS turn-on transitions as all the switches in the DC-DC converter circuit used for the utility AC 200V-rms input.

The operating waveforms of the circuit for the AC 400V-rms input are almost the same as that of the converter circuit for the AC 200V-rms input. The main difference between circuit operation with AC 200V and circuit operation with AC 400V is that the voltage  $v_C$  across the capacitor  $C$  is not clamped to DC busline voltage in case of the circuit for AC 400V-rms input.

### IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

#### A. System Implementations for 200V and 400V Utility AC

The experimental setups for the soft-switching PWM DC-DC power converter circuits with high frequency transformers for either the utility AC 200V-rms or AC 400V-rms dual inputs are respectively implemented in Fig. 6 and Fig. 7, respectively.

In Table1, the design specifications and circuit parameters are listed respectively. Under the both DC-DC power converter circuits shown in Fig. 6 and Fig. 7, the 2in1 IGBT power modules 2MBI150TA-060( $I_C=150A$ ,  $V_{CES}=600V$ ) produced by Fuji Electric Co. Ltd are used for all the active switches. In Fig. 6, each IGBT with reverse conducting diode in the 2in1 IGBT power modules is used for the switches  $Q_5(S_5/D_5)$  and  $Q_6(S_6/D_6)$  and another IGBT with reverse conducting diode in the 2in1 IGBT power modules is not in use. In Fig. 7, each IGBT with reverse conducting diode and one reverse conducting diode in the 2in1 IGBT power modules are used for the active PWM switches  $Q_5(S_5/D_5)$ ,  $D_9$  and  $Q_6(S_6/D_6)$ ,  $D_{10}$ . Observing Table 1, all the switches and components used in Fig. 6 and Fig. 7 are completely the same ones.

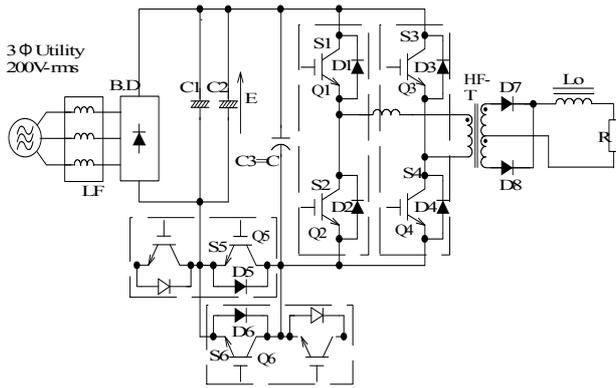


Fig. 6 Experimental setup for utility AC 200V-rms input

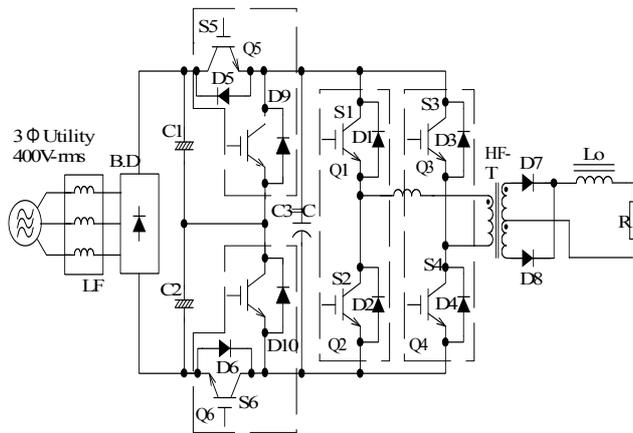


Fig. 7 Experimental setup for utility AC 400V-rms input

Table 1 Design specification and circuit parameters

Item	Symbol	Value
Switching Frequency	$f_s$	40[kHz]
Leakage Inductance of High Frequency Transformer	$L_s$	2[ $\mu$ H]
Capacitance of Smoothing	C1	1880[ $\mu$ H]
Capacitance of Smoothing	C2	1880[ $\mu$ H]
Capacitance of Quasi Resonance Capacitor	C3	0.1[ $\mu$ F]
Inductance of DC Reactor in load side	$L_o$	100[ $\mu$ H]
Load Resistance	R	0.1 $\Omega$
Maximum Load Current	$I_o$	350[A]
Turns Ratios of Transformer windings	$N_1:N_2:N_2$	5:1:1

Fig. 8 demonstrates the whole appearance of the experimental setup using CO<sub>2</sub>/MAG arc welding power supply for both utility AC 200V-rms and AC 400V-rms input. The maximum output rating of this experimental setup is 36V, 350A (12.6kW).

Fig. 9 represents the assembled component appearance in the primary side of the main power converter circuit used in the experimental setup in Fig. 6.

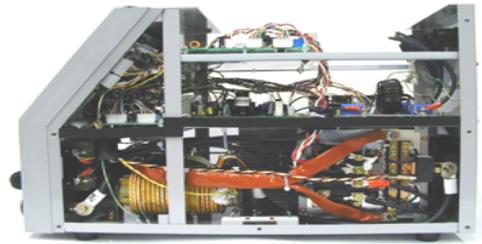


Fig. 8 Whole appearance of experimental setup of CO<sub>2</sub>/MAG arc welding power supply for both utility AC 200V-rms and AC 400V-rms input

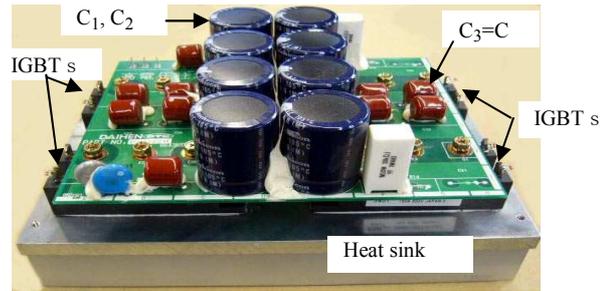


Fig. 9 Assembled component appearance in transformer primary side circuit of soft-switching PWM DC-DC power converter

The only difference on the assembled components in the primary side of the main DC-DC power converter circuit between the experimental setups in Fig. 6 and in Fig. 7 should be the printed circuit board designed for the circuit connections.

The IGBT modules are mounted on the heat sink and connected by the printed circuit board on which the capacitors C<sub>1</sub>, C<sub>2</sub> and C<sub>3</sub>=C are mounted. Connecting IGBTs, the capacitors C<sub>1</sub>, C<sub>2</sub> and C<sub>3</sub>=C by the printed circuit board enables to minimize the stray inductance at wiring connections among IGBTs, C<sub>1</sub>, C<sub>2</sub> and C<sub>3</sub>=C. Actually, the minimum leakage inductance assembled by the printed circuit board connections is particularly important factor on this newly-developed soft-switching PWM DC-DC power converter, because spike voltage across collector and emitter of IGBTs easily appears at a turn off dynamic transition if there is wiring stray inductance between the snubbing capacitor C<sub>3</sub>=C and the IGBT switches in full-bridge inverter arms and DC busline.

### B. Measured Switching Waveforms

In experimental implementation, the switching operating waveforms for voltage and current under maximum output power (36V, 350A) for utility AC 400V-rms input when the switch Q<sub>1</sub> is turned on and turned off are depicted in Fig. 10 (a) and (b), respectively.

Observing these waveforms in Fig. 10, the switch Q<sub>1</sub> is turned on with ZCS and turned off with ZVS. The switching voltage and current waveforms under a maximum output power ratings (36V, 350A) are respectively shown in Fig. 10 (c) and (d) when the switch Q<sub>5</sub> is turned on and turned off.

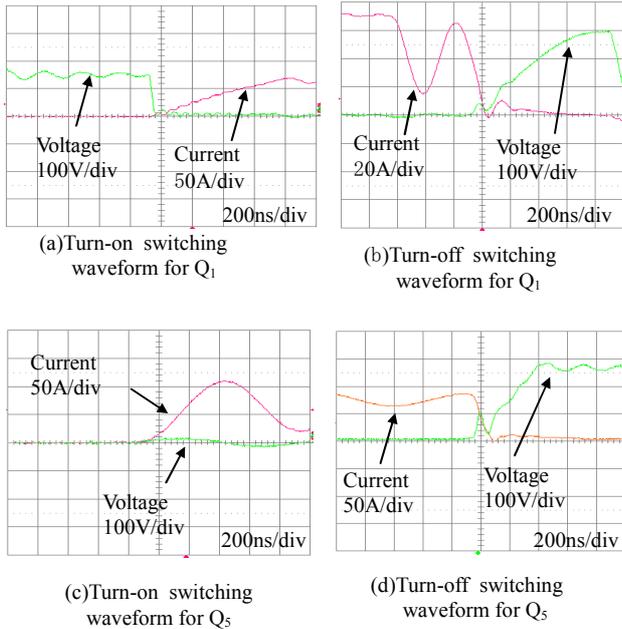


Fig. 10 Measured switching voltage and current waveforms for the switches  $Q_1$ ,  $Q_5$  under the circuit for utility AC 400V-rms input

Observing the operating waveforms, the switch  $Q_5$  is completely turned on with ZVS/ZCS and is turned off with ZVS. However, at the turn-off mode transition processing for switches  $Q_1$  and  $Q_5$ , some power losses still exist due to inherent tail current characteristic of the used IGBTs.

### C. Power Loss Analysis

Considering power loss analysis in Fig. 11, the total power losses of all the active switches in the full-bridge arms including  $Q_5$  and  $Q_6$  in DC busline for the newly-developed soft-switching PWM DC-DC power converter circuits for utility AC 200V-rms and AC 400V-rms input shown in Fig. 6 and Fig. 7 are compared with those of all the switches in conventional hard-switching PWM inverter type DC-DC converters. When the switching frequency is about 20 kHz, the total power losses for soft-switching PWM DC-DC inverter type power converter circuit and hard-switching PWM inverter type DC-DC converter are almost equal. When the switching frequency of voltage source full-bridge high frequency inverter power stage using IGBTs is designed so as to be more than about 20 kHz, the more the switching frequency of full-bridge high frequency inverter increases, the more this newly-developed DC-DC power converter circuits can have remarkable advantages from the view points of the power conversion efficiency and power density as compared with those of the conventional hard-switching inverter type DC-DC power converters.

In case the switching frequency is designed for 40 kHz or the ripple frequency 80 kHz, the total power losses for all the switches in newly-developed soft-switching PWM DC-DC power converter circuits with a high frequency inverter are 405 W in case of AC 200V-rms input and 465 W in case

of AC 400V-rms input, respectively. On the other hand, those of the conventional hard-switching PWM inverter type DC-DC converters are 510 W and 600 W, respectively. Furthermore, the RC snubber circuit is necessarily for the conventional high frequency transformer link hard-switching PWM DC-DC power converter circuit. Therefore, the total power losses for conventional high frequency transformer link hard-switching PWM DC-DC power converter circuits including the power loss of RC snubber circuit are estimated as about 785 W in case of AC 200V-rms input and 1100 W in case of AC 400V-rms input, respectively. These power losses are about two times more than the total power loss of newly-developed converter circuit in case of AC 200V-rms input and two times more than that in case of AC 400V-rms input.

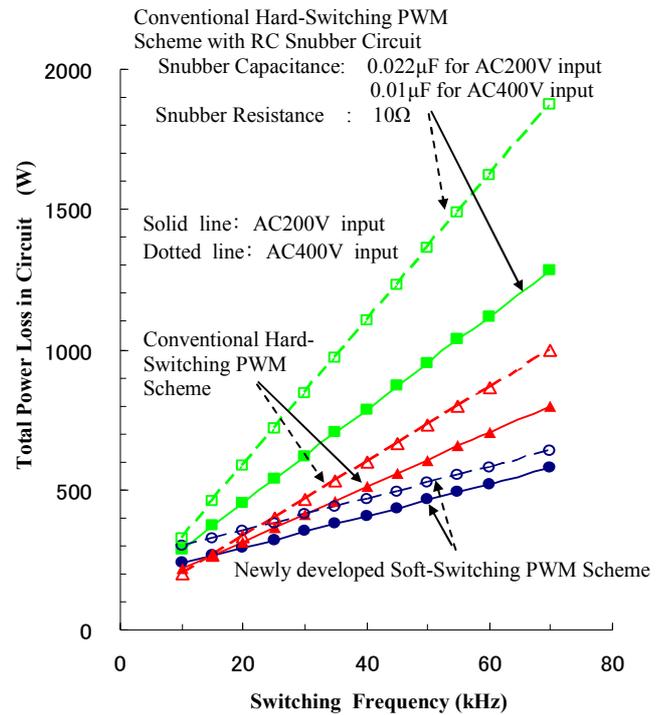


Fig. 11 Comparative power loss analysis between newly-developed soft-switching PWM and conventional hard-switching PWM DC-DC power converters

### D. Arc Welding Products

Under the experimental setup implementation of  $CO_2/MAG$  arc welding power supply equipment shown in Fig. 8 using the proposed power converter, the volumetric size is 59% less and its weight is 47% less than these of conventional  $CO_2/MAG$  arc welding power supply equipment using hard-switching PWM inverter using IGBT power modules, because the newly-developed high frequency transformer link soft-switching PWM full-bridge DC-DC power converter circuit enables 40 kHz switching frequency for the new generation  $CO_2/MAG$  arc welding power supply equipment without increasing the power loss of the power switches, while the inverter switching

frequency of conventional arc welding power supply equipment is designed so as to be 13 kHz for hard-switching PWM operation. In addition to this, the arc welding dynamic performance can be much improved by high control responses in accordance with the high switching frequency.

## V. CONCLUSIONS

In this paper, two new circuit topologies of soft-switching PWM DC-DC power converters with high frequency transformer suitable and acceptable for utility AC 200V-rms or 400V-rms dual voltage input specifications were presented, which are composed of voltage source-fed full-bridge inverter with additional series PWM switches in DC busline and a parallel lossless capacitive snubber between DC busline ports, a high frequency transformer with its secondary side winding center tapped configuration, a full-wave diode rectifier and a DC reactor in series with the load.

The power loss analysis of soft-switching PWM DC-DC power converters with a high frequency transformer link were discussed and evaluated as compared with that of hard-switching PWM DC-DC power converters with high frequency transformer link. The practical effectiveness of the proposed DC-DC power converters operating under soft-switching PWM scheme were actually proved from a practical point of view for utility AC 200V and AC 400V and the high efficiency and power density of two type of power converters could be achieved on the basis of the experimental results for the latest CO<sub>2</sub>/MAG arc welder put into practice.

The main features of newly-developed soft-switching PWM DC-DC power converters with a high frequency transformer applications circuit can be summarized as follows;

( i ) By adding a simple circuit configuration of additional semiconductor switching devices connected in series with DC rail and a passive paralleled power capacitor component to the conventional full-bridge hard-switching PWM inverter, all the active switching devices can achieve ZVS turn-off and ZCS turn-on soft commutation. Therefore, although the total conduction power losses of the additional switches increase a little, the total turn-off switching loss of voltage source full-bridge type PWM inverter can be significantly decreased when the switching frequency of high frequency inverter power stage using IGBTs is selected more than about 20 kHz.

( ii ) The newly-developed DC-DC power converter circuits can be used for both utility AC 200V-rms and AC 400V-rms dual voltage input line without replacing any semiconductor switching devices and high frequency transformer by means of changing lead wiring connections only. Thus, the newly-developed soft-switching PWM DC-DC power converter circuit with a high frequency transformer has a cost effective applicability for the utility AC 200V/400V input voltage.

( iii ) The control circuit for newly-developed circuits can be implemented easily by modifying the conventional PWM signal processing circuit using common PWM control

IC ( $\mu$  PC494).

In the future, the high frequency IGBTs and IEGTs as well as IESB should be applied and evaluated for the newly-proposed DC-DC power converter and the cascaded SiC-JFETs and SiC-SBD in the new generation high frequency power semiconductor devices should be considered for the proposed high frequency soft-switching PWM DC-DC power converter with a high frequency transformer link including synchronous rectifier suitable for low voltage and large current output. Furthermore, the active three phase PWM rectifier to reduce the harmonic current in the utility AC 200V-rms or AC 400V-rms power source line has to be considered for this type of application. Moreover, the current source type soft-switching PWM DC-DC power converter as a circuit duality topology of voltage source type soft-switching PWM DC-DC power converter circuit treated here and these diverse applications in industry should be investigated comparatively with the aid of high frequency transformer assembly and configuration.

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