An Innovative DC Busline Active Snubber-Assisted Soft Switching
PWM DC-DC Power Supply with High Frequency Transformer
for High Performance Arc Welder

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Abstract— This paper presents three novel circuit topologies of voltage
source soft switching PWM inverter with full-bridge or
half-bridge configurations suitable for either utility ac 200V-rms
or ac 400V-rms input ac line. The proposed power converters
are composed of typical full-bridge or half-bridge inverter and
additional power semiconductor switching devices for dc busline
PWM series switching with the aid of lossless capacitive
snubbers. Under the newly-proposed soft switching PWM dc-dc
power converter circuits with high frequency transformer, all the
active power switches in the full-bridge arms or half-bridge arm
and dc busline can actively achieve ZVS turn-off and ZCS or
ZVS/ZCS turn–on 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 or half-bridge inverter
increases, the more soft switching PWM dc-dc power converter
with a high frequency transformer has remarkable advantages
for its power conversion efficiency and power density as
compared with the conventional hard switching PWM inverter
type dc-dc converters. The effectiveness of this new converter
topologies are 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 bridge
topologies, High frequency transformer link, 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
to 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 three novel circuit topologies of voltage
source full-bridge or half-bridge type soft switching PWM
inverter suitable for either utility ac 200V-rms or ac 400V-rms
input line, which are composed of typical full-bridge or half-
bridge inverter and additional semiconductor switching
devices for dc busline PWM series switching with the aid of
lossless capacitive snubbers. Under the newly-proposed soft
switching PWM full-bridge or half-bridge dc-dc power
converter circuits with high frequency transformer, all the
active switches in the full-bridge arms or half-bridge arm and
de busline can actively achieve ZVS turn–off and ZCS or
ZVS/ZCS commutation operation.

The steady state operating principles of the soft switching
PWM full-bridge or half-bridge dc-dc power converters tested
here are described, along with its remarkable features. The
experimental operation results of those new types of soft
switching PWM full-bridge or half-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 converters. The practical effectiveness of the proposed soft switching PWM full-bridge or half-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. NEW SOFT-SWITCHING PWM DC-DC CONVERTER

A. Schematic Circuit Description

Fig. 1 shows a basic full-bridge configuration of newly-developed dc busline active snubber-assisted soft switching PWM dc-dc converter with high frequency transformer, 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-tapped 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 Q4(S4/D4) and Q6(S6/D6) 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 Q1(S1/D1), Q2(S2/D2), Q3(S3/D3) and Q4(S4/D4). In particular, a single lossless snubbing capacitor C is inserted between active switches Q5, Q6 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. The gate voltage pulse signals with a certain dead time, which are delivered to Q1 and Q4 or Q2 and Q3 in the voltage source full-bridge inverter arms, are the same as signal sequences of conventional full-bridge inverter. Regarding the turn-on gate voltage pulse signals to the dc busline side series switches Q2 or Q6, the gate signals are applied to Q2 or Q6 at the same timing period as the turn-on gate pulse signals to Q1 and Q4 or Q2 and Q3, respectively. As for the turn-off gate voltage pulse signals to Q3 or Q6, the gate pulses are delivered to Q3 or Q6 before the predetermined specific length of time td on the basis of the time when the turn-off signals are respectively applied to the switches Q1 and Q4 or Q2 and Q3.

C. Circuit Operation Principle

Fig. 3 illustrates the relevant operating waveforms for the basic full-bridge configuration 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 t0 to t6 and its operation principle is described in the following. The equivalent circuits corresponding to each mode are shown in Fig.4.

1) Mode 0 : \( t_0 \) Before time \( t_0 \), the switches Q1, Q4 and Q3 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 Q5 in dc busline side is turned off simultaneously. At this time, the series switch Q5 can be turned off with ZVS because the current \( i_{Q5} \) through Q5 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,

\[
v_c(t) = E - \left( \frac{i_{L1}(t_0)}{C} \right) t \tag{1}
\]

Where, \( i_{L1}(t_0) \) is a primary current of high frequency transformer at time \( t = t_0 \) and \( i_{L1}(t_0) \) is closely resembled to be constant after the series switch Q5 is turned off. From the eq. (1), the discharging time \( t_d \) of the capacitor C until the voltage \( v_c \) becomes zero is given by,

\[
t_d = \frac{CE}{i_{L1}(t_0)} \tag{2}
\]

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 \( i_{L1}(t_0) \) and the maximum output current. In this case, switches Q1, Q3 or Q2 and Q3 can achieve ZVS transition completely. If we need to widen
the complete ZVS operation range at the turn-off commutation for the switches Q1 and Q4 or Q2 and Q3, the optimum delay time $t_d$ should be varied according to the value of the transformer primary current $i_{t1}$.

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 Q2 and $D_3$ of Q3 are turned on and the current $i_{t1}$ 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 Q1 and Q4 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 Q2 and $D_3$ of Q3 immediately turn on, the active switches Q1 and Q4 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).

$$\frac{1}{2}CE^2 = \frac{1}{2} LS (i_{t1}(t_0))^2$$

$$t_d \sim t_2$$

For the basic full-bridge configuration

Fig. 3 Operating waveforms of the basic full-bridge configuration during one switching period

Fig. 4 Equivalent circuits of seven operational modes for the basic full-bridge configuration
However, as described after, in mode 6, the circuit parameters should be designed to meet the condition of \((1/2)CE^2 \leq (1/2)L_s(f_{i1}(t))^2\) in order to achieve ZVS commutation at turn-on transition of the switch Q6.

5) **Mode 4 :** \(t_4 \sim t_5\) Under a condition of \((1/2)CE^2 < (1/2)L_s(f_{i1}(t))^2\), 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 \(D_9\) of \(Q_3\) 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 :** \(t_5 \sim t_6\) 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 :** \(t_6 \sim t_7\) 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.

### III. FULL-BRIDGE CONFIGURATION WITH HALF VOLTAGE BUCK DC-DC CONVERTER

**A. Circuit Description**

Fig. 5 shows a soft switching PWM dc-dc power converter circuit using full-bridge configuration with half voltage buck dc-dc converter. Under the circuit of full-bridge configuration with half voltage buck dc-dc converter, 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 \(Q_1\) 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 \(Q_3\) 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 full-bridge configuration with half voltage buck dc-dc converter are exactly the same as that for the basic full-bridge configuration in Fig. 2. Under the full-bridge configuration with half voltage buck dc-dc converter, when the switches \(Q_3\) or \(Q_6\) are turned on and turned 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.

In addition to this feature, when the switches \(Q_1, Q_4\) or \(Q_3\) or \(Q_6\) are turned on and turned off alternately at the same timing pulses as those for the switches in the dc-dc converter using the basic full-bridge configuration 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 with the basic full-bridge configuration.

The operating waveforms of the circuit using full-bridge configuration with half voltage buck dc-dc converter are almost the same as that of the converter circuit using the basic full-bridge configuration. The main difference of circuit operation between the basic full-bridge configuration and full-bridge configuration with half voltage buck dc-dc converter circuit is that the voltage \(v_c\) across the capacitor C is not clamped to dc busline voltage in case of the circuit for full-bridge configuration with half voltage buck dc-dc converter.

### IV. HALF-BRIDGE CONFIGURATION WITH HALF VOLTAGE BUCK DC-DC CONVERTER

Fig. 6 shows a soft switching PWM dc-dc power converter circuit using half-bridge configuration with half voltage buck dc-dc converter. The pattern sequences of switching gate driving pulse for half-bridge configuration with half voltage buck dc-dc converter is also exactly same as that for basic full-bridge configuration shown in Fig.2.

Under the circuit of half-bridge configuration with half voltage buck dc-dc converter, there are two lossless snubber capacitors \(C_a\) and \(C_b\) (\(C_a = C_b = C\)) and the power switches \(Q_3\) and \(Q_4\) are deleted from full-bridge configuration shown in Fig. 5. Under this configuration, when the power switches \(Q_1, Q_3\) or \(Q_2, Q_6\) are turned on and turned off alternately at the same timing pulses as those shown in Fig. 2, all the active power switches can also perform ZVS turn-off transition and perform ZCS or ZVS/ZCS turn-on transition as well as all the power switches in the circuit of basic full-bridge configuration and full-bridge configuration with half voltage buck dc-dc converter shown in Fig. 1 and Fig. 5. In this configuration, the
lossless snubber capacitor $C_1$ works for ZVS turn-off transition of $Q_2$ and the lossless snubber capacitor $C_2$ works for ZVS turn-off transition of $Q_1$.

The feature for half-bridge configuration as compared with full-bridge configuration with half voltage buck dc-dc converter is that power loss can be decreased because power switches $Q_3$ and $Q_4$ are eliminated and high frequency transformer current $i_{t1}$ does not flow through the diodes $D_9$ and $D_{10}$ during turn-on period of $Q_5$ or $Q_6$.

![Soft-switching PWM dc-dc power converter circuit using half-bridge configuration with half voltage buck dc-dc converter](image)

V. EXPERIMENTAL RESULTS AND DISCUSSIONS

A. Feasible System Implementations

The experimental setups using the basic full-bridge configuration for utility ac 200V-rms input, the full-bridge configuration with half voltage buck dc-dc converter for utility ac 400V-rms input and the half-bridge configuration with half voltage buck dc-dc converter for utility ac 400V-rms input are shown in Fig. 7, Fig. 8 and Fig. 9, respectively. In Table 1, the design specifications and circuit parameters are listed respectively.

In Table 1, the $C_4$ is only for the circuit shown in Fig. 9 and values of other circuit parameters in three converter circuits are exactly same. Under the full-bridge configuration shown in Fig. 7 and Fig. 8, 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. 7, 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. 8, 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 $Q_6(S_6/D_6)$, $D_{10}$. Under the half-bridge configuration shown in Fig. 9, same 2in1 IGBT power modules 2MBI150TA-060($I_c=150A$, $V_{CES}=600V$) as those in the full-bridge configuration are used for active PWM switches $Q_5(S_5/D_5)$, $D_9$ and $Q_6(S_6/D_6)$, $D_{10}$ and 2in1 IGBT power modules 2MBI150SC-120($I_c=150A$, $V_{CES}=1200V$) are used for the switches $Q_1(S_1/D_1)$ and $Q_2(S_2/D_2)$.

![Experimental setup of the basic full-bridge configuration for utility AC 200V-rms input](image)

![Experimental setup of the full-bridge configuration with half voltage buck dc-dc converter for utility AC 400V-rms input](image)

![Experimental setup of the half-bridge configuration with half voltage buck dc-dc converter for utility AC 400V-rms input](image)

Fig. 10 presents the whole appearance of experimental setup using the circuit of basic full-bridge configuration and full-bridge configuration with half voltage buck dc-dc converter for CO2/MAG arc welding power supply. The maximum output rating of this experimental setup is 36V, 350A (12.6kW).
Table 1  Design specification and circuit parameters

<table>
<thead>
<tr>
<th>Item</th>
<th>Symbol</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Switching Frequency</td>
<td>fs</td>
<td>40[kHz]</td>
</tr>
<tr>
<td>Leakage Inductance of High Frequency Transformer</td>
<td>Ls</td>
<td>2[µH]</td>
</tr>
<tr>
<td>Capacitance of Smoothing</td>
<td>C1</td>
<td>1880[µH]</td>
</tr>
<tr>
<td>Capacitance of Smoothing</td>
<td>C2</td>
<td>1880[µH]</td>
</tr>
<tr>
<td>Capacitance of Quasi Resonance Capacitor</td>
<td>C3</td>
<td>0.1[µF]</td>
</tr>
<tr>
<td>Capacitance of Quasi Resonance Capacitor</td>
<td>C4</td>
<td>0.1[µF]</td>
</tr>
<tr>
<td>Inductance of DC Reactor in load side</td>
<td>L0</td>
<td>100[µH]</td>
</tr>
<tr>
<td>Load Resistance</td>
<td>R</td>
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<tr>
<td>Maximum Load Current</td>
<td>Io</td>
<td>350[A]</td>
</tr>
<tr>
<td>Turns Ratios of Transformer windings</td>
<td>N1:N2 :N2</td>
<td>5:1:1</td>
</tr>
</tbody>
</table>

Fig. 11   Assembled component appearance in transformer primary side circuit of basic full-bridge configuration and full-bridge configuration with half voltage buck dc-dc converter

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 Q1 is turned on and turned off are depicted in Fig. 12 (a) and (b), respectively. Observing these waveforms in Fig. 12, the switch Q1 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. 12 (c) and (d) when the switch Q5 is turned on and turned off. Observing the operating waveforms, the switch Q5 is completely turned on with ZVS/ZCS and is turned off with ZVS. However, at the turn-off mode transition processing for switches Q1 and Q5, some power losses still exists due to inherent tail current characteristic of the used IGBTs.

Fig. 12 Measured switching voltage and current waveforms for the switches Q1, Q5 under the full-bridge configuration with half voltage buck dc-dc converter in case of utility ac 400V-rms input
C. Power Loss Analysis

Considering power loss analysis in Fig. 13, the total power losses of the switches in three newly-developed soft switching circuits are compared with those of all the switches in conventional hard switching PWM inverter type dc-dc converters under the condition of maximum output power (36V, 350A). Three lines for newly-developed soft switching PWM converter in Fig. 13 indicate the total power losses of all the active switches in the basic full-bridge configuration in case of utility ac 200V-rms input shown in Fig. 7, the total power losses of all the active switches and diodes D₉, D₁₀ in the full-bridge configuration with half voltage buck dc-dc converter in case of utility ac 400V-rms input shown in Fig. 8 and the total power losses of all the active switches and diodes D₉, D₁₀ in the half-bridge configuration with half voltage buck dc-dc converter in case of utility ac 200V-rms input is 405 W, the total power losses of all the active switches and diodes D₉, D₁₀ in the full-bridge configuration with half voltage buck dc-dc converter in case of utility ac 400V-rms input is 465 W and the total power losses of all the active switches and diodes D₉, D₁₀ in the half-bridge configuration with half voltage buck dc-dc converter in case of utility ac 400V-rms input is 325 W, respectively.

In the case of utility ac 200V-rms input shown in Fig. 7, 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 high frequency inverter power stage using IGBTs is designed so as to be more than about 20 kHz, the more the switching frequency of high frequency inverter increases, the more this newly-developed dc-dc power converter circuit 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 Table 2, features of comparative three newly-developed soft switching PWM dc-dc power converters with high frequency transformer are described. This experimental setup of CO₂/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.

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 the basic full-bridge configuration in case of utility ac 200V-rms input is 405 W, the total power losses of all the active switches and diodes D₉, D₁₀ in the full-bridge configuration with half voltage buck dc-dc converter in case of utility ac 400V-rms input is 465 W and the total power losses of all the active switches and diodes D₉, D₁₀ in the half-bridge configuration with half voltage buck dc-dc converter in case of utility ac 400V-rms input is 325 W, respectively. On the other hand, those of the conventional hard switching PWM inverter type dc-dc converters are 510 W in case of ac 200V-rms input and 600 W in case of utility 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.

D. Industrial Arc Welding Products

Under the experimental setup implementation of CO₂/MAG arc welding power supply equipment shown in Fig. 10 using the circuit of basic full-bridge configuration and full-bridge configuration with half voltage buck dc-dc converter, the volumetric size is 59% less and its weight is 47% less than these of conventional CO₂/MAG arc welding power supply equipment with 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 CO₂/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.
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is selected more than about 20 kHz.

loss of voltage source full-bridge or half-bridge type PWM additional switches increase a little, the total turn-off switching turn-off and ZCS or ZVS/ZCS turn-on soft commutation.

can be summarized as follows;

rail and passive paralleled capacitor components to the applications circuit can be summarized as follows;

VI. CONCLUSIONS

In this paper, three 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 or half-bridge inverter with additional series PWM switches in dc busline and parallel lossless capacitive snubbers 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 were discussed and evaluated as compared with that of hard switching PWM dc-dc power converters with high frequency transformer. 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 three type of power converters could be achieved on the basis of the experimental results for the latest CO2/MAG arc welder put into practice.

The main features of newly-developed soft switching PWM dc-dc power converters with a high frequency transformer application 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 passive paralleled capacitor components to the conventional full-bridge or half-bridge hard switching PWM inverter, all the active switching devices can achieve ZVS turn-off and ZCS or ZVS/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 or half-bridge type PWM inverter can be significantly decreased when the switching frequency of high frequency inverter power stage using IGBTs

(ii ) The newly-developed full-bridge inverter type 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 ) In the half-bridge configuration with half voltage buck dc-de converter, a switching device used in inverter arm should be different from that in the basic full-bridge configuration. However, the total power losses in all the active switches and additional diodes D9 and D10 in the half-bridge configuration with half voltage buck dc-de converter is smaller than that for other two full-bridge configurations.

In the future, the high frequency IGBTs and IEGT should be applied for the newly-proposed dc-dc power converters and the cascade SiC-JFETs and SiC-SBD in the new generation high frequency power semiconductor devices should be considered for the proposed converters.

REFERENCES


