Performance Improvement of Isolated High Voltage Full Bridge Converter Using Voltage Doublers


Abstract – The performance of an isolated high voltage full bridge converter is improved using a voltage doubler. In a conventional high voltage full bridge converter, the diode of the transformer secondary voltage undergoes a voltage spike due to the leakage inductance of the transformer and the resonance occurring with the parasitic capacitance of the diode. In addition, in the phase shift control, conduction loss largely increases from the freewheeling mode because of the circulating current. The efficiency of the converter is thus reduced. However, in the proposed converter, the high voltage dual converter consists of a voltage doubler because the circulating current of the converter is reduced to increase efficiency. On the other hand, in the proposed converter, an input current is distributed when using parallel input / serial output and the output voltage can be doubled. However, the voltages in the 2 serial DC links might be unbalanced due to line impedance, passive and active components impedance, and sensor error. Considering these problems, DC injection is performed due to the complementary operations of half bridge inverters as well as the disadvantage of the unbalance in the DC link. Therefore, the serial output of the converter needs to control the balance of the algorithm. In this paper, the performance of the conventional converter is improved and a balance control algorithm is proposed for the proposed converter. Also, the system of the 1.5[kW] PCS is verified through an experiment examining the operation and stability.

Keywords: Fuel cell, PCS(Power Conditioning System), Dual converter, Full bridge converter, DC/DC converter, SOB(Serial Output Voltage Balance) control

1. Introduction

Recently, due to high oil prices, the need to cope with the growing demands for supply securities of alternative energy and electricity has increased, along with the need to address the increasing environmental problems [1, 2]. Thus, the research and development currently being carried out in developed countries focus mainly on fuel cells [3], photovoltaics [4], and wind power generation [5] etc., as future technologies for solving the environmental and energy problems. In photovoltaic, wind power, and tidal power generation, while infinite clean energy can be obtained, it cannot be secured due to the nature of the surrounding environments. Consequently, many studies regarding the fuel cells system have been actively performed. The fuel cells system has characteristics of low voltage and high current output. Thus, studies regarding the effective utilization of the Power Conditioning System (PCS) have been actively performed. In the PCS, it is very important to choose a topology according to the power capacity; the PCS topology is applied in industries through compact, high-efficiency, and densification in low-power systems [6]. Also, apart from studies on the basic electrical circuit of the power supply, a modularization method utilizing the power supply through modularization of the chosen circuits is studied. Among the modularization methods, the modularization of parallel input / serial output connects the input side of the multiple power supply modules in parallel and the output side in series to supply the total output voltages from each module to the load side. Particularly, it is very useful for composing a voltage boosting type of power supply. The representative voltage boosting types of power supply are push-pull [7], half bridge [8], and full bridge converters. The push-pull and half bridge converters can more easily reduce the semiconductor than general full bridge converters. However, the cost is increased due to the use of a heat sink with a high rated semiconductor. The full bridge converter is widely used in the applied fields. Because it has good stability with the use of the transformer, it is used for a high electric power. Also, the full bridge converter can perform soft switching by using the parasites in the circuit without the need for additional circuits. However, it cannot satisfy all of the soft switching conditions of lagging-leg switches within the ranges of all loads [9]. Also, a snubber circuit is needed for the voltage resonance of the diode due
to the resonance at the transformer secondary voltage [10]. Therefore, in the proposed system, the transformer secondary voltage is integrated with the voltage doubler to overcome the weakness of the conventional full bridge converter. The doubler is designed to satisfy the soft switching conditions. By applying a phase shift method in the designed circuit, soft switching can possibly be performed in all loads. Also, the proposed converter is composed of a parallel input / serial output by using the dual converters. The half bridge inverter is composed of the output capacitor of the serial converter. While the disadvantage of the half bridge inverter is that it increases the voltage of the DC link capacitor more than the full bridge inverter, it also reduces the cost and volume with 2 switches [11]. However, in the proposed voltage doubler dual converter, the voltages in 2 serial DC links might be unbalanced due to line impedance, passive and active components impendence, and sensor error. Considering these problems, DC injection is performed due to the complementary operations of the half bridge inverters as well as the disadvantage of the unbalance in the DC link port. Using these DC injections, the power components in the sine wave of the fundamental frequency are decreased. If the clamping power is connected to the load, the load malfunctions.

In a proposed voltage doubler dual converter, the input current is distributed when using a parallel input / serial output and the output voltage can be doubled. Also, the voltage spike of the diode is clamped using a voltage doubler and the freewheeling current is reduced in the freewheeling mode. The voltages in 2 serial DC links might be unbalanced due to line impedance, passive and active components impendence, and sensor error. Therefore, the Serial Output voltage Balance (SOB) control algorithm is proposed for balance voltage of the serial output in the transient and steady state.

2. System Configuration

2.1 Fuel cell hybrid generation

In this paper, PCS is used for the AC output using fuel cells hybrid generation. The fuel cells have a very low response speed [12, 13]. Therefore, energy from additional energy storage is required such as a battery or supercapacitor when the initial load is increased. Even if the energy supply is temporarily stopped from the fuel cells, the reliability of the system can be improved with a power supply from the battery [14, 15]. Also, in the individual type of fuel cells system, the Balance Of Plant (BOP) of fuel cells requires an auxiliary power supply to supply the power when it is initially operated, supplying power from the controller when using the battery voltage. Therefore, the battery is added to the system to ensure effective use of energy.

Fig. 1. Fuel cell hybrid generation system using high voltage battery

Fig. 2. Fuel cell hybrid generation system using low voltage battery

Fig. 3. Fuel cell hybrid generation system using bidirectional power converter and low voltage battery

Fig. 1 shows the fuel cell hybrid generation system using a high voltage battery.

The high voltage battery is connected between the output of the converter and the input DC link of the inverter.

When the load increased, the output current of the fuel cell is limited and the current is immediately supported from the high voltage battery.

If the fuel cell is capable of supplying enough current from the load, the battery is also charged. However, the disadvantages of the high voltage battery are that it increases the cost and the battery voltage is unbalanced when used for a long period of time.

Fig. 2 shows the fuel cell hybrid generation system using a low voltage battery. In the low voltage battery, the problems of the high voltage battery are solved.

Fig. 3 shows the fuel cell hybrid generation system using a bidirectional power converter and a low voltage battery. While the utilization of the fuel cell and battery allows for easy charge and discharge, the system increases the overall cost and the system efficiency decreases. Thus, considering the advantages and disadvantages of the system, the fuel cell hybrid generation uses a low voltage battery in the proposed system, as shown in Fig. 2.

2.2 Proposed power conditioning system

In the proposed fuel cell hybrid generation, the output
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The proposed system shows high efficiency through soft switching in all loads.

- The number of devices increases more than with full-bridge converter. However, the heat dissipation is easy and the volume of the entire system can be reduced.
- Conduction loss was reduced by eliminating the large current for the free-wheeling section in the primary side of the transformer.
- The current is divided by connecting the input side of the converter in parallel and the output voltage is increased by connecting the output side of the converter in series. Therefore, it is possible to design a low turn ratio of the transformer.

Also, the proposed dual converter is designed without an additional resonant circuit. Operation waveforms are explained for all operation modes and the proposed system is designed using a mathematical model. The phase shift control method is controlled for soft switching and the interleaved control method is controlled for a minimum input current. Also, SOB is controlled for balancing the control of the output voltage. The phase half bridge inverter is applied Phase Lock Loop (PLL) using the All Pass Filter (APF). The block diagram of the proposed system is shown in Fig. 4. The proposed system is verified in the experiment results at a rate of 1.5[kW], input voltage of 60[V], and an output voltage of 220[Vrms].

### 2.3 Converter operation mode analysis

Fig. 5 shows the converter module A in the voltage double dual converter. Module A and module B of the converter had the same operations, so the modes were analyzed in terms of the use of the converter module A. In the modes analysis, the converter modes were divided into 8 modes for analysis. The V~Ⅲ modes were similar to the 1~Ⅲ modes. Therefore the V~Ⅲ modes were omitted. Here, it was assumed that the junction capacitance of the diode was not conventional and constituted 100% of...
the load in the modes analysis. Even though waveforms could be slightly differentiated in other conditions, the sections were performed identically in the 8 modes.

The operation mode of the proposed converter is shown in Fig. 6. The important waveforms showed switching signals, transformer primary voltages, primary currents, and doubler capacitor currents.

In Mode 1 ($t_0 \sim t_1$), the transformer primary $I_{po}$ increase and the transformer energy passed to the load. If the previous mode had a negative direction to the flowing transformer current, the current flow will be in a negative direction through the body diode of the switch because of the stored leakage inductance and magnetizing inductance energy. The switch $S_2$ voltage is equal to zero and the turn on signal is given to the switch $S_2$ under the zero-voltage condition. The transformer current is increased in a positive direction by input voltage. At this time, the transformer energy passes to the load. After leakage inductance, $L_{lk}$ and the doubler capacitor $C_r$ start their resonance. Thus, the transformer current is expressed by (1).

$$I_{po}(t) = \frac{1}{n} \left[ \frac{V_n}{n} - V_{po}(t_0) \right] \frac{1}{Z_0} \sin \omega_r (t - t_0) + I_{lm}(t - t_0) \quad (1)$$

where,

$$n = \frac{N_r}{N_p}, Z_0 = \frac{L_{lk}}{C_r}, \omega_r = 2\pi f = \frac{n}{\sqrt{L_{lk}C_r}}.$$

$$C_r = C_{al} // C_{a2}$$

The resonance frequency is expressed by (2). $\omega_m$ is the resonance frequency of the magnetizing inductance and doubler capacitor. $\omega_r$ is the resonance frequency of the leakage inductance and doubler capacitor. The $\omega_m$ is smaller than the resonance frequency $\omega_r$. Also $\omega_r$ can be approximated linearly. The current of the rectifier diode $D_1$ flows through $C_{al}$ and the equivalent load, while the doubler capacitors $C_{al}$ and $C_{a2}$ are charged and discharged respectively.

$$\frac{\omega_m}{\omega_r} = \sqrt{\frac{L_{lk}}{L_{m}}}$$

where,
$$\omega_n = 2\pi f_n = \frac{n}{\sqrt{L_mC_r}}$$

In Mode II \((t_1 \sim t_2)\), switch \(S_1\) is turned off. The output capacitance of switch \(S_1\) is charged. The output capacitance voltage and input voltage have been equalized. At this time, the transformer secondary voltage sustains the doubler capacitor voltage \(V_{c1}\). Therefore, the transformer primary voltage is \(nV_{c1}\). The leakage inductance voltage of the transformer is expressed by (3). Subsequently, the leakage inductance current of the transformer is rapidly decreased.

When the diode voltage becomes a reverse voltage, the output capacitance of the switch is charged.

$$V_{\text{lk}g} = V_p - V_{\text{pri}}$$  \((3)\)

In Mode \(\text{III}(t_2 \sim t_3)\), the loss of the entire system increases due to the impedance of the circuit. Therefore, this mode should be considered when designing the magnetizing inductance.

The switch \(S_2\) is turned off in Mode \(\text{IV}(t_3 \sim t_4)\). The voltage \(V_{\text{lk}g}\) of the leakage inductance is charged from the output capacitance of the switch. The current flow forms residual energy through the body diode of switch \(S_3\). Switch \(S_3\) voltage is equal to zero and the turn on signal is given to switch \(S_2\) under the ZVS condition.

3. ZVS for Leakage Inductance and Voltage Doubler Capacitance Design

In the dual converters, the leakage inductance of the high frequency transformer was used to charge and discharge the switch output capacitor. If the leakage inductance as insufficient, the ZVS condition of the lagging leg switch in the low load cannot be created. In the suggested converter, the current flowing in the leakage and magnetizing inductance must charge and discharge the 2 leading leg switches and the output capacitor of the 2 lagging leg switches. To charge and discharge the output capacitor of the leading-leg switch, refer to the following. It was assumed that the output capacitance of all switches was the same.

$$\frac{1}{2}L_{\text{lk}g}i_{\text{pri}}^2 + \frac{1}{2}L_{\text{m}}i_{\text{in}}^2 \geq \frac{1}{2}2C_{\text{out}}V_o^2 \quad \text{(4)}$$

At this time, \(I_{\text{pri}}\) sharply decreased to be the same as \(I_{\text{in}}\) due to the small leakage inductance. Here, the current flowing in the magnetizing inductances should be sufficient to charge and discharge the output capacitor of the lagging-leg switch. Thus, the energy of the magnetizing inductance should satisfy the following condition. \(C_{\text{out}}\) was confirmed to be \(4.1[nF]\) in reference to the datasheet of the switch.

$$\frac{1}{2}L_{\text{nk}}i_{\text{in}}^2 \geq \frac{1}{2}2C_{\text{out}}V_o^2 \quad \text{(5)}$$

The leakage inductance of the transformer was calculated as \(1.5[\mu H]\), and the magnetizing inductance was calculated as \(160[\mu H]\).

The voltage doubler rectifier consists of the \(C_1\) and \(C_2\) serial capacitors because the boost ratio is increased to the output voltage. The resonance frequency \(f_r\) is set to 0.84 of the time of the switching frequency \(f_s\). The resonance frequency can be represented by (6). If the doubler capacitance is summarized, it can be calculated.

$$\omega_r = 2\pi f_r = \frac{n}{\sqrt{L_{\text{nk}}C_r}} \quad \text{(6)}$$

$$C_r = \frac{1}{L_{\text{nk}}} \left(\frac{n}{2\pi f_r}\right)^2 \quad \text{(7)}$$

4. Performance Improvement of System

4.1 Performance improvement of conventional full bridge converter

The operation of the conventional full bridge converter delivers the electricity of the DC input voltage to the output side through semiconductor switching components. It boosts the voltage according to the turn ratio of the high frequency transformer. The output voltage of the voltage-boosted converter passes through the secondary diode rectifier and filter to become the output of the rectified waveform.

Fig. 7. Transformer magnetizing and diode voltage according to conventional converter
Fig. 7 shows the transformer primary voltage and current and transformer secondary diode voltage according to the gate signal of the conventional full bridge converter. The conventional full bridge converter performs soft switching when using the leakage inductance and output capacitances of the switching components without additional circuits. However, in the conventional full bridge converter, the soft switching was only performed in specific sections according to the loads in order to reduce the loss in switching. Also, as shown in Fig. 7, the circulating current occurs in the non-powering freewheeling mode with the change in the duty cycle when the $S_2$ and $S_4$ switches are switched on.

Therefore, the loss in the switch circuit increases. Afterwards, the switches of $S_1$ and $S_4$ or $S_2$ and $S_3$ are turned on to deliver the energy to the secondary electricity section. At this time, the resonance phenomenon occurs in the diode voltage, causing stress. Therefore, the rated voltage of the diode and separate snubber circuits is also needed.

The current of the transformer primary and diode voltage in the voltage doubler dual converter are shown in Fig. 8. To overcome the disadvantage of the conventional full bridge converter, a voltage doubler rectifier was used for the transformer secondary diode rectifier. In the voltage doubler rectifier, the filter inductor in the output can be removed, thus partly restraining the resonance in the transformer secondary leakage inductance and diode output capacitance; also, clamping of the doubler capacitor with the output voltage can be performed in the diode, even if resonance occurred due to the parasites. Also in the phase shift control, the size of the freewheeling current was decreased to reduce the conduction loss in the circuit.

Some of the freewheeling current was charged to the transformer secondary doubler capacitor to be decreased.

### 4.2 Problem improvement of converter output voltage

The series capacitor was used in both the suggested converter output and the inverter input. Thus, in the converter and inverter, the voltages of capacitors should be controlled. In the half bridge inverter, the complementary operation of the switch causes unbalance in the DC link port to perform DC injection in the output voltage. Due to these DC injections, the electricity components in the sine wave of the fundamental frequency were decreased. If clamped power is injected in the electrical load, incorrect operation and malfunction of the load occurred. Safety accidents can occur in the load system where the power was injected simultaneously with the electric power load. To remove the occurrence of DC injection, a separate additional circuit was needed.

When the output capacitor was controlled by the voltage doubler dual converter, the additional circuit was not needed. However, unbalance can occur in the voltage of the output capacitor due to a sensor error of the converter, parasitic impedance of the passive and active components, and line impedance.

Fig. 9 shows the output voltage of each converter module according to the conventional control method. Each converter has the same controller gain and the steady state response is further delayed because of the different transient responses. The output response characteristic according to the proposed SOB control is shown in Fig. 10. The proposed SOB control method shows the same response.

Since the output of the proposed voltage double dual
converters was connected to the capacitor in series, it must be improved to allow the dual converters to follow the same output voltage of the reference output voltage. The proposed algorithm was only composed of a voltage controller. Generally, the voltage converter used voltage and current controllers that were connected in series to control the output. It was very important to choose an appropriate bandwidth of the controller for the system when using the current controller and voltage controller, which had an effect of increasing the quick-response of the current controller according to the controlling width. However, the system might be unstable since it became sensitive to the noise of the current sensor signals. Therefore, if the bandwidth of the voltage controller is controlled to be 1/10 less than the bandwidth of the current controller reduces. However, if it was limited by 1/10, the quick-response of the voltage control became slower. Therefore, in this paper, the proposed converter is controlled using a voltage controller.

Fig. 11 shows a flowchart of the reference generation algorithm.

In the SOB control algorithm, if the output voltage of the converter module is not equal, the output voltage is subtracted from the large output voltage to a small output voltage. The difference in error value is calculated in (8) and then substituted to (9). If the reference from which the calculated error is subtracted is inputted to the converter having a larger output voltage, the voltages of the two converters have the same output voltage.

\[
V_{\text{out,Err}} = \left| V_{\text{out,A}} - V_{\text{out,B}} \right| \quad (8)
\]

\[
\begin{align*}
V_{\text{ref, A}} &= V_{\text{ref}} - V_{\text{out,Err}} \quad (V_{\text{out,A}} > V_{\text{out,B}}) \\
V_{\text{ref, B}} &= V_{\text{ref}} - V_{\text{out,Err}} \quad (V_{\text{out,A}} < V_{\text{out,B}})
\end{align*}
\]  

(9)

If the target output voltage and converter output voltage were not the same, the controller repeated these controlling processes until it achieved the target output voltage. Consequently, both voltage values were equally produced. It was difficult to control the gain value of the controller when using multiple converters connected in series in the modularized converter since the response characteristics of each converter differed. Therefore, the gain value of the converters in the modularized converter was the most sensitive to the control. However, in the SOB controlling algorithm, the converter modules of the serial output were controlled to be the same, regardless of whether the gain value of the controller had the same output dynamic characteristics.

5. Experimental Results

In order to prove the theoretical analysis, experiments were conducted on the proposed systems as shown in Fig. 12. The proposed system consists of 60[V] batteries, a fuel cell simulator and PCS for the experiment.

The voltage double dual converter and half bridge inverter are shown in Fig. 13. The right side of the
The proposed system is the converter and the left side is the inverter. The controller used was TMS320F28335. The control algorithm of the converter uses phase shift control for soft switching and 90° interleaved control for reduction of input current. The control algorithm of the inverter used a PLL with an APF.

Table 1 shows the system parameters of the system. The output voltage of the converter modules is controlled to 350[V]. The converter and inverter switching frequency are 30[kHz] and 10[kHz], respectively. The fluctuation of the inverter input voltage occurred due to the disadvantages of the DC injection because the inverter switches have complementary operation. In order to remove the fluctuation, the switching frequency of the converter was selected as three times faster than the switching frequency of the inverter. Thus, through this frequency, the capacitor was controlled.

The gate signals of the voltage doubler dual converter in phase shift control are shown in Fig. 14. Each converter was controlled using the phase shift control method to reduce the switching losses of the converters.

The gate signals of the voltage doubler dual converter with interleaved control are shown in Fig. 15. The interleaved control method was used to reduce the current ripple for the battery and fuel cell generation. The interleaved control method was operated with a 90° phase difference.

Table 1. System parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage</td>
<td>60</td>
<td>V</td>
</tr>
<tr>
<td>Input current</td>
<td>25</td>
<td>A</td>
</tr>
<tr>
<td>Converter output voltage</td>
<td>700</td>
<td>V</td>
</tr>
<tr>
<td>Converter output current</td>
<td>2.14</td>
<td>A</td>
</tr>
<tr>
<td>Inverter output voltage</td>
<td>220</td>
<td>V</td>
</tr>
<tr>
<td>Inverter output current</td>
<td>6.8</td>
<td>A</td>
</tr>
<tr>
<td>Trans turns ratio</td>
<td>4 : 16</td>
<td>Turn</td>
</tr>
<tr>
<td>Trans leakage inductance</td>
<td>1.5</td>
<td>μH</td>
</tr>
<tr>
<td>Doubler capacitance</td>
<td>1.5</td>
<td>μF</td>
</tr>
<tr>
<td>Converter filter capacitance</td>
<td>1000</td>
<td>μF</td>
</tr>
<tr>
<td>Inverter filter inductance</td>
<td>300</td>
<td>μH</td>
</tr>
<tr>
<td>Converter switching frequency</td>
<td>30</td>
<td>kHz</td>
</tr>
<tr>
<td>Inverter switching frequency</td>
<td>10</td>
<td>kHz</td>
</tr>
</tbody>
</table>

In Fig. 16, switch $S_1$ is turned on under the ZVS operation of the leading-leg switch $S_1$ and the voltage and current of the switch are shown. The stored energy of the leakage inductance and magnetizing inductance flows to the body diode of the switch. When both ends of the switch voltage are '0' state, switch $S_1$ is turned on for the ZVS operation.

Fig. 17 is turned on under the ZVS operation of the lagging-leg switch $S_3$. When switch $S_3$ is turned off, the output capacitance and leakage inductance starts the resonance. Switch $S_3$ is then turned on under the zero voltage condition.

The transformer primary voltage and current waveforms of the conventional full bridge converter are shown in Fig. 18. Fig. 18 generally shows, the magnetizing current transformer primarily in the freewheeling mode. The magnetizing current causes conduction loss to occur in

![Fig. 14. Gate signals of the voltage doubler dual converter with phase shift control](image)

![Fig. 15. Gate signals of voltage doubler dual converter at phase shift control](image)

![Fig. 16. ZVS turn-on operation of leading-leg $S_1$](image)

![Fig. 17. ZVS turn-on operation of lagging-leg $S_3$](image)
The transformer primary voltage current waveforms of the proposed converter are shown in Fig. 19. The proposed converter decreased the magnetizing current of the transformer primary voltage in the freewheeling mode because the voltage doubler uses the influence of the capacitor reduced magnetizing current.

The output diode voltage and output current of the conventional dual converter are shown in Fig. 20. The voltage oscillation causes voltage stress in the freewheeling mode. The maximum voltage stress was more than three times the maximum output voltage. Thus, in the case of the traditional dual converter, a snubber circuit is also required.

The diode voltage and current of the proposed dual converter is shown in Fig. 21. The output inductor is removed using the voltage doubler rectifier. Therefore, the voltage oscillation can be removed when the diode is turned off. Also, a snubber circuit is required because the diode voltage is clamped at the output voltage of 350[V].

Fig. 22 shows the output voltage and DC_link voltage of converter modules A and B. The output voltage of each converter is the same in the steady state. As a result, the DC_link voltage is controlled at 700[V].

Fig. 23 shows the capacitor voltage and output voltage of converter module A.
Fig. 24. Output voltage and current of fuel cell simulator according to load

Fig. 25. Input and output voltage and current of converter according to load

Fig. 26. Output voltage and current of the phase half bridge inverter

The output voltage and current of the fuel cell simulator according to load are shown Fig. 24. In the case of the fuel cell simulator, the voltage decreases and the current increases at a higher load. Power is established as 1.5[kW].

The input and output voltage and current converter voltage according to the load are shown in Fig. 25. For verification, the control performance of the converter confirmed the input and output of the converter through a variable load.

The output voltage and current of the phase half bridge inverter are shown in Fig. 26. The voltage of the input capacitor can be generated by the DC injection because of the complementary operation of the inverter. Thus, the switching frequency of the converter was selected as three times faster than the switching frequency of the inverter.

According to the input and output voltage, the current of the inverter is shown in Fig. 27. For verification, the control performance of the inverter confirmed the input and output of the inverter through a variable load. The phase of the voltage and current is controlled by a power factor of 1.

Fig. 28 shows the output voltage of the proposed dual converter using general PI control when the voltage reference is applied. The output voltage of the converter is
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The reference of the proposed dual converter and output voltage is shown in Fig. 29. The output voltage of the proposed dual converter is balanced at the SOB control and the transient state is improved.

The hybrid generation system according to the load is shown in Fig. 30. In the case of the proposed system, the voltage and current of the fuel cell simulator and battery are confirmed. The fuel cell hybrid generation system can operate efficiently and continuously. If the reformer of the fuel cell cannot generate, the fuel cell generation systems operate using a battery. In this case, the battery is in the discharge mode. After operation of the fuel cell generation systems, the battery is in the charge mode and the required energy to load is supplied by the fuel cell generation system. In this case, the battery is in the charge mode and the fuel cell system is in the generation mode. If the battery is charged at a constant voltage, the charge current at the battery is reduced.

The efficiency comparison of the proposed converter and conventional converter is shown in Fig. 31. The efficiency of the proposed converter was measured using a power analyzer (WT 3000). The proposed converter is 92% more efficient in all loads and the maximum efficiency is shown as 96.1%. Also the conventional dual converter consists of a full bridge converter. The conduction loss of the transformer and voltage stress of the diode occurred with the conventional dual converter. To reduce conduction loss, the freewheeling current of the transformer is decreased to a minimum and the diode rectifier change voltage doubled to reduce voltage stress. Also in order to reduce copper loss, turns ratio of transformer is reduced using voltage doubler. The phase half bridge inverter has an efficiency of 97%.

6. Conclusion

In this paper, the performance of a power conditioning system using a voltage double dual converter and a phase half bridge converter is improved. In addition, a series output voltage balance control algorithm is proposed for output voltage balance. In the case of the proposed system, the advantages of the system include efficiency and lower rated devices due to the connected parallel input / series output. Also, the proposed algorithm can be used for constant output voltage regardless of sensor error, parasitic of passive and active devices, and converter control gain. Also, the connected plural converters can be practically controlled at a constant output at a transient response. It is expected that the development of power conversion using renewable sources will be helped through the proposed system.

Acknowledgements

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Science, ICT & Future Planning(No: 2014R1A2A2A05006744)

References


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