SNUBBERLESS CURRENT FED HALF BRIDGE ISOLATED CONVERTER
FOR FUEL CELL APPLICATIONS

Raghavendra H S¹, Nagaraj A M²

¹PG Student, Dept of EEE, DSCE, Bangalore-78
²Asso. Prof. Dept of EEE, DSCE, Bangalore-78

ABSTRACT

This paper presents a new class of current fed converter for a power electronic interface for fuel cell applications, photovoltaic inverters, etc. The proposed circuit shows advantage over conventional hard switched current fed half bridge isolated dc/dc converter and active clamped ZVS current fed half bridge isolated dc/dc converter with a simple solution to switch turn-off voltage spike problem without any additional snubber as in active clamped ZVS converter. It leads in reduced size, lower cost, and higher efficiency. A formal mathematical description was arriving at design parameters is also touched upon, for 250W converter. The results of the proposed topology are study in detail through simulation in PSIM 9.0 platform and results are presented with efficiency of 95%.

Keywords: Fuel cell inverter, Half bridge isolated converter, current fed converter, Zero current switching (ZCS), dc/dc converter.

I. INTRODUCTION

With the concept of smart grid, smart metering, smart buildings, alternative energy sources, transportation electrification, hybrid micro-grid, etc., efficient, economical, and compact power conversion is getting increasing importance, and power electronics industries are revoking. So many alternative energy sources have been implementing as a hybrid with a present energy sources or some using as a complete alternative to them. In those alternative fuel cells are more dominating which as huge applications such as stationary loads, automotive applications, and interfaces with electric utilities due to the several advantages over conventional other alternative sources. To effectively utilize energy resources, the development of fuel cell generation systems is becoming increasingly important for global environment. The fuel cell, a clean and renewable energy source, has recently been revived and shows promising results for applications as small as cellular phones to
as large as utility power generations. This particular fuel cell system is intended for household stand-alone power generation.

Fuel cells output is continuous and secure as long as the fuel supply is maintained unlike PV and wind. Fuel cell vehicles are true zero-emission vehicles and which are getting commercial attraction these days. Energy storage in gas (H2 and O2) form relieves from issues like disposal, lifetime, leakage, deep discharging, overcharging, and capacity variations with season in case of battery storage. Therefore, fuel cell systems will dominate in future smart grid.

The fuel cell systems consist of front end dc/dc converters and followed by an inverter to converter the obtained dc to ac loads. This is shown in block diagram in Fig. 1(a).

A fuel cell stack consists of an individual low-voltage cell as in block {1}; therefore, from a cost standpoint, minimum number of cells used to reduce the cost. Most of the fuel cell manufacturers have chosen a standard voltage of 28–43 Vdc.

This low-voltage characteristic requires that the output voltage of the fuel cell stack (input voltage of the inverter) should be boosted before it is inverted to ac source as in block {2}, so inverter is added with a dc–dc converter on the front end. Sinusoidal AC source is again converted back to DC with bridge circuits as in block {3}, before delivering to load {5} supply will filtered for requirement {4}.

Front-end dc/dc conversion is highly important in fuel cell inverters because its efficiency dominates the overall system efficiency. Selection of efficient and high performance converters is important. Many such converter and inverter topologies are presented and compared based on their performance and other parameters. Looking at the configurations of the circuits they are mainly of current fed and voltage fed converter configurations. The conventional voltage fed converter configurations are not optimal due to the several ripple current characteristic of the fuel cell. In order to handle the ripple current, a large number of electrolyte capacitors are essentially required, resulting in an increase in the overall system size and manufacturing cost. Moreover, in voltage fed converters, high winding ratio between the primary and secondary sides of the high frequency transformer is necessary because the boosting action is only performed by the winding ratio and it also causes the snubber to be enlarged to handle the surge at turn-off switching instants. Whereas, in the current fed converters using an inductor decreases the current ripple as well as the electrolyte capacitor size. An active boosting action can also be achieved with relatively low winding ratio. Therefore, for the fuel cell system current fed converter is a better choice than the conventional voltage fed converter.

In current fed converter topologies switching of devices is being experimenting in order to obtain the better efficiency from hard switching to soft switching using zero current switching (ZCS) and zero voltage switching (ZVS) techniques. Fig. 1(b) shows conventional hard switching current fed technique circuit, due to switching losses in this technique of switching it is preferable to use soft switching technique [3].
Fig. 1(b): Conventional hard switched current fed half bridge isolated dc/dc converter

Fig. 1(c): Lossless snubber current fed converter

Fig. 1(d): Active lossless snubber current fed converter

Fig. 1(e): Active clamping current fed half bridge converter

Fig. 1(b) show the lossless snubber current fed converter which will operate only at turn off and its circuit is too much complicated, Fig. 1(c) shows the active lossless snubber converter here both turn on and turn off operates at zero-voltage switching(ZVS) but the voltage across the auxiliary switches are twice of the main switch[2].
Fig. 1(d) shows the active clamping current fed half bridge converter. This circuit switches operates at zero voltage switching. This circuit increases the current stresses across the components and introduces circulating current that leads to higher switch rms current. With that, it requires two additional active switches, two snubber capacitors, and one high-frequency (HF) capacitor of large value, which increases the component count and converter complexity.

In this paper, a fuel cell generation system with a ZCS current fed half-bridge dc/dc converter with full bridge on secondary has been implemented. The proposed converter boosts the low output voltage (30 Vdc) of fuel cell stack to high dc voltage, such as 500 Vdc in a high efficient manner. The proposed 250 w converter analyses and design are verified by simulation results using PSIM 9.0. The rest of the paper addresses the operation principle, design consideration and simulation results.

II. SYSTEM DESCRIPTION

Proposed zero-current-switching (ZCS) current fed half-bridge dc/dc converter is shown in fig 2. In this converter voltage across the switches is clamped without an active clamp or passive snubber, which leads in reduction in size and cost. It improves the converter efficiency by ZCS of primary devices, zero-current turn-on of all devices, and natural commutation of secondary diodes and body diodes of primary devices. Switching transition losses are significantly reduced. It has negligible circulating current and lower conduction losses and, therefore, is expected to show better light load efficiency than hard switching and active-clamped circuits. This ZCS current fed half bridge dc/dc converter is having bidirectional ability and can be used for battery storage, fuel cell vehicles, and hybrid electric vehicles. Circuit consists of a current fed half bridge converter on the primary side of the high frequency transformer, and secondary side having full bridge converter [1].

Converter consists of a half bridge converter at primary side converting constant Vdc to AC voltage with the help of two switches S1, S2. Series inductor (Ls) is used for boosting purpose and to decrease the ripple current. Specially designed high frequency transformer of turns ratio 1:n is to used to step up the voltage to n times the converted voltage. Then with the full bridge at the secondary side of transformer the AC voltage is then converted back constant DC voltage, the full bridge circuit consists of IGBT’s as the switches used accordingly to obtain desired output. The gating sequence of the primary switches and secondary switches are inter related, switch S3 and S6 turn on before switch S2 turns off meanwhile switch S4 and S5 turn on before switch S1 turns off. The primary switch S1 and S2 are operated with gating signal which are 180° phase shift and the reflected output voltage Vo/n appears across the transformer primary. This diverts the current from the primary switch into the transformer, causing the transformer current to decrease to zero. Once current decreases below zero, the body diode across the switch starts conducting, and the gating signal is removed, causing its ZCS turn-off.
III. DESIGN CONSIDERATION

To verify the feasibility of circuit, the proposed converter built on following specifications after designing [1]:

- Input voltage: \( V_{in} = 30 \text{ V} \);
- Output voltage: \( V_{out} = 500 \text{ V} \);
- Output power: \( P_o = 250 \text{ W} \);
- Operating frequency: \( f = 100 \text{K Hz} \);
- Voltage conversion ratio: \( n = 4 \);
- Series inductor: \( L_s = 15\mu\text{H} \);
- \( L_1 \) and \( L_2 = 228\mu\text{H} \);
- Load resistor = 1K\( \Omega \);
- Output capacitor = 2.6\( \mu\text{F} \);
- Primary switch duty ratio = 0.76;
- Secondary switch duty ratio = 0.05;

After considering all these parameters and simulated using PSIM 9.0 simulation software the overall efficiency obtained is 95%.

IV. SIMULATION RESULTS

In this section, simulation results for a 250 W converter design are verified using PSIM 9.0.

Fig. (7) shows the PSIM simulation circuit with designed parameters. The following assumptions are made for converter analysis:

- Inductors \( L_1 \) and \( L_2 \) are large enough to maintain constant current through them
- Magnetizing inductance of the transformer is infinitely large
- All the components are ideal
- \( L_s \) is the leakage inductance of the transformer or a secondary inductor that includes the transformer leakage inductance.

Fig. 7: Proposed ZCS Current Fed Half Bridge Dc/Dc Converter
Current flowing through the boost inductors is exactly half of the input current, which is obtained because of the 180° phase shift obtained from primary switches. The phase shifting can be clearly observed in Fig. 9.
Fig. 11 shows the each switch current reaches zero naturally and anti-parallel body diode conducts, causing a zero voltage across it. Therefore, gate signal is removed without any additional snubber needed for switch turn-off.

Fig. 12: Current Flowing Through the Secondary-Side Switches

Fig. 12 shows the zero current turn-on of secondary switches as the current starts conducting from zero and builds up with a slope that depends upon the reflected value of Ls.

Fig. 13: Voltage across the secondary switch

Fig. 14: Voltage across the primary switch

The voltage across the primary switch will be $V_o/n$, where $n$ is transformer turn’s ratio. Which can verified using Fig. 13 and Fig. 14.

Fig. 15: Waveform showing output voltage
V. CONCLUSION

In this paper, a current fed half-bridge isolated dc/dc converter with operates in ZCS proposed for fuel cell applications. In particular, compare with other previous converter topologies this converter is more efficient with following advantages low cost, simple circuit and less components. The following converter has been verified with PSIM 9.0 simulation tool and the efficiency of 95% has been recorded.

VI. REFERENCES