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Implementation of PID controller for an Interleaved Buck-Boost Converter for Fuel Cell Applications

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Abstract

In this study, an interleaved Tri-state Buck-boost converter (ITBBC) for fuel cell applications is designed and developed.The proposed ITBBC's has good transient performance . The ripple factor is also decreased as a result of the Tri-state approach. Signals are sent and controlled using PID controllers, or proportional and integral controllers. The suggested ITBBC's output voltage response under load transient conditions has been studied. The transient response and voltage ripple is reduced by the proposed converter. Additionally, due to the interleaving technique and suitability for fuel cell applications.

Keywords— boost converter, tri-state, PID controller, right half plane zero

Introduction

Buck-boost converter is a DC-DC converter used to increase or decrease the source voltage [1]. Electric vehicle charging, Fuel cell Systems, and Solar PV applications all use buck-boost converters as power sources [2]–[3].By implementing Tri-state operation, RHP zero in Buck-Boost Converters can be removed. [5]. Tri-state Buck-Boost converter is a buck boost converter with extra mode called freewheeling mode,The absence of right-half-plane zero transfer function,improves the dynamic performance of the converter. However, the inclusion of the freewheeling mode has the drawback of increasing output voltage ripple. The interleaving technique can be used to get around this.

The two Buck-Boost converters are connected in parallel and operated at Interleaving state to form the ITBBC.Two Buck-Boost converters are operated using the interleaving technique with a 180° phase difference. The transfer function of proposed converter is calculated using state space averaging method .

Under various load situations, it has been seen that the proposed interleaved converter exhibits a robust and faster transient response and also creates less ripple than existing Buck-Boost converters. Power efficiency will rise as a result of decreased ripple.

Tri-state Interleaved Buck-Boost Converter

In the Figure 1 is shows the proposed converter.MOSFET devices (S_{m1} and S_{m2}), MOSFET devices (S_{f1} and S_{f2}), main diodes (D_{m1} and D_{m2}), freewheeling diodes (D_{f1} and D_{f2}), inductors (L_1 and L_2), capacitor (Co), and resistor are all components of the proposed interleaved tri-state buck-boost converter (R). The input and output voltages are V_i and V_o respectively. The Interleaved Tri-state Buck-Boost Converter's steady-state current waveforms of inductor(i_{L1} and i_{L2}) for buck and boost operations are depicted in Fig (2). In one switching cycle, The operating mode of Tri-state Buck-Boost converter are charging, discharging, or freewheeling as seen in Fig. (2). (D_{ch1} and D_{ch2}) and (D_{dis1} and D_{dis2}) are the ITBBC duty cycles for charging and discharging, and (D_{f1} and D_{f2}) diodes respectively. Fig. 2 shows the steady-state operation of ITBBC.The suggested Interleaving tri-state Buck-Boost converter performs better in change in load operations and has good efficiency .

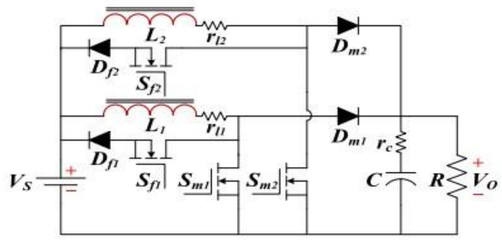


Fig 1. Tri-State Interleaved Buck-Boost Converter

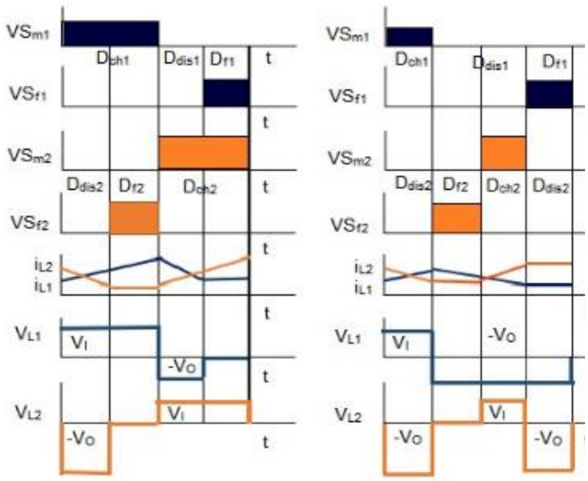


Fig 2. Current and voltage waveforms in the (a) boost mode and (b) buck mode

Interleaved Buck-Boost Converter Modelling

The converter is transformed into a linear system using the SSA approach. Equation (1) contains the equations for the first interleaved Buck-Boost converter (2)

$$\begin{bmatrix} \frac{di_{L1}}{dt} \\ \frac{dv_O}{dt} \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & \frac{-1}{RC} \end{bmatrix} \begin{bmatrix} i_{L1} \\ V_O \end{bmatrix} + \begin{bmatrix} \frac{1}{L_1} \\ 0 \end{bmatrix} V_1 \quad (1)$$

$$\begin{bmatrix} \frac{di_{L1}}{dt} \\ \frac{dv_O}{dt} \end{bmatrix} = \begin{bmatrix} 0 & \frac{-1}{L_1} \\ \frac{1}{C} & \frac{-1}{RC} \end{bmatrix} \begin{bmatrix} i_{L1} \\ V_O \end{bmatrix} \quad (2)$$

$$\begin{bmatrix} \frac{di_{l1}}{dt} \\ \frac{dv_O}{dt} \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & \frac{-1}{RC} \end{bmatrix} \begin{bmatrix} i_{L1} \\ V_O \end{bmatrix} \quad (3)$$

Similarly, the state equations of second interleaved Buck-Boost converter is given in (3)

$$\begin{bmatrix} \frac{di_{L2}}{dt} \\ \frac{dv_O}{dt} \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & \frac{-1}{RC} \end{bmatrix} \begin{bmatrix} i_{L2} \\ V_O \end{bmatrix} \quad (4)$$

$$\frac{V_O(S)}{D_{ch}(S)} = \frac{V_S}{\frac{L_{eqC}}{D_{dis}}} s^2 + \frac{L_{eq}}{RD_{dis}} + D_{dis} \quad (5)$$

It can be seen from (4) that the right half of plane zero is deleted. Equation (5) .

$$\frac{V(s)}{D_b(s)} = \frac{26}{5.875*10^{-7}S^2+2.5*10^{-5}S+0.2} \quad (6)$$

The equation (6) shows that the converter don't have right half plane zero.

Hardware Implementation of ITBBC Converter

The optimization is done using PID Controller because it enhances the system's stability and lowers the steady-state error. The controller reduces the error.Figures 4 and 5(a) and 6 show the output waveforms and hardware implementation, respectively (b). Two 50kHz signals at 1800 degrees out of phase were produced by a control circuit using a dsPIC30F2010 microcontroller. Strong signals were converted and sent to the switches using an opto-coupler. Four MOSFET switches were driven 180^0 degrees out of phase by the signals from the opto-coupler.

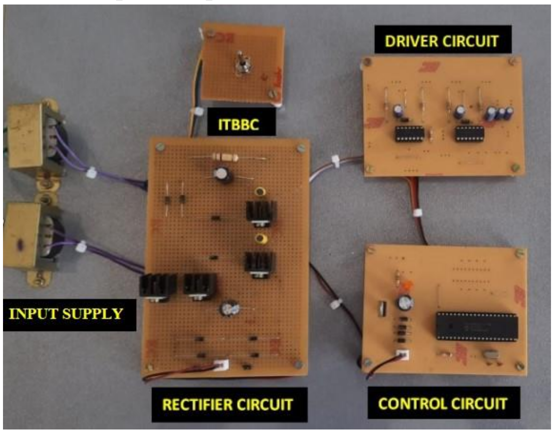
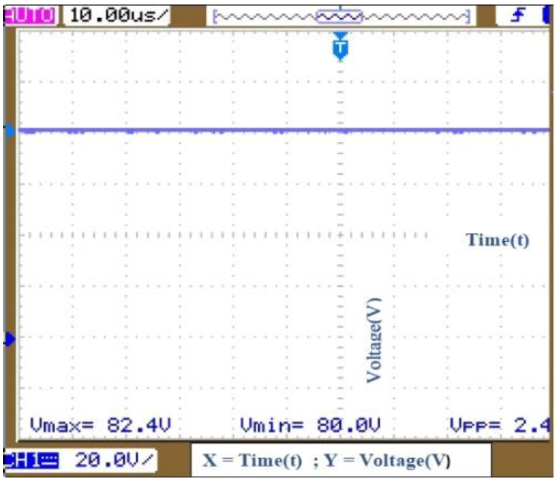


Fig 4. Hardware circuit of proposed converter



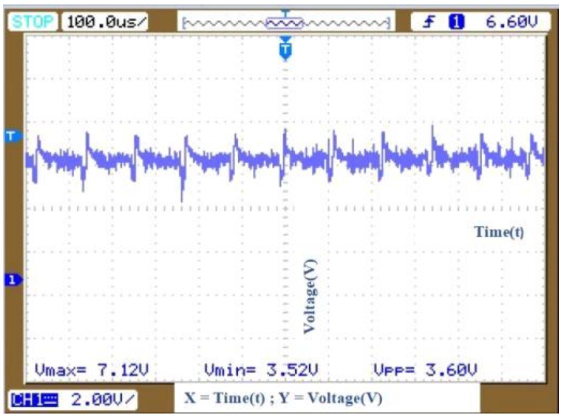
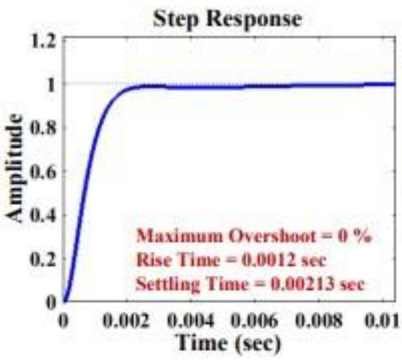


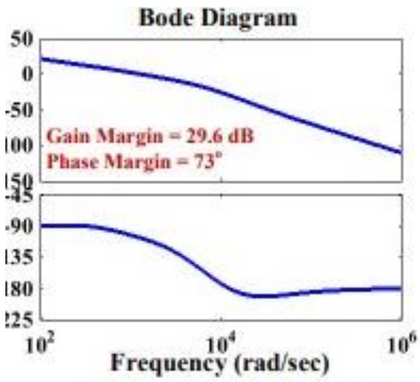
Fig.5.
(a) Output waveform of ITBBC(Boost mode)
(b) Output waveform of ITBBC(Buck mode)

Hardware Results and Discussion

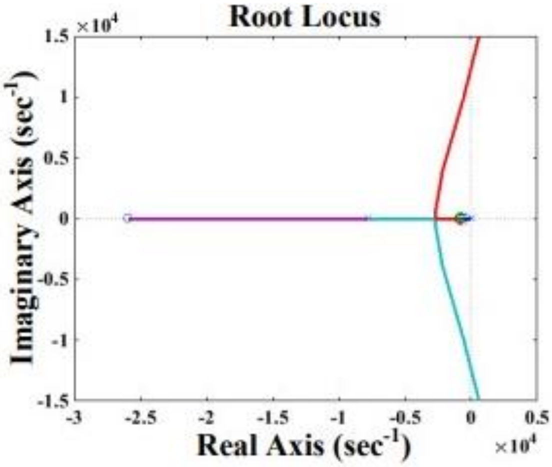
The designed hardware is tested and the output voltage is 3.6V in Buck mode and 80.8V in Boost mode. In order to evaluate the proposed ITBBC's transient performance in closed loop conditions, time response and a bode diagram are plotted (b). In a closed loop system, the suggested Interleaved Tri-state Buck-Boost converter performs well during transient conditions.



(a) Time response



(b) frequency response



(c) Pole zero map

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Conclusion

The suggested Interleaved Buck-Boost converter responds to load changes more quickly than other converters. Compared to previous Buck-Boost converters, it also has less ripple in output voltage and a increased efficiency. This ITBBC exhibits good transient responsiveness making it suitable for Fuel Cell applications.The ITBBC system can be further optimized using Fuzzy Logic and ANN algorithms which is the future study

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