INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN: 2278 – 0211 (Online)

Small Signal Ac Modelling Of A Multimode Single-Leg Power Converter

Athulya P Prem
M.Tech
School of electrical sciences ,Karunya University, Coimbatore, India
Chinnu P Ravi
M.Tech
School of electrical sciences ,Karunya University, Coimbatore, India
SudhinGovind
M.Tech
School of electrical sciences ,Karunya University, Coimbatore, India

Abstract:
This paper presents a small signal ac modeling of a multimode single leg power converter to control the power flows between sources, batteries, and ultracapacitors. The proposed multimode single-leg power converter substitutes the boost converter and bidirectional converter with a multifunctional bidirectional converter. To verify the performance of the proposed system, its operations are categorized and explained to four different modes. Then, each mode of the proposed system is modeledand final small signal ac equivalent circuit of model is obtained.

Key words: *Bidirectional converter, small signal modeling, renewable energy, hybrid vehicles, power conversion*

I. Introduction

Bidirectional dc-dc converters (BDC) have recently received a lot of attention due to the increasing need for systems with the capability of bidirectional energy transfer between two dc buses. Apart from traditional application in dc motor drives, new applications of BDC include energy storage in renewable energy systems, fuel cell energy systems, hybrid electric vehicles (HEV) and uninterruptible power supplies (UPS).

In this paper, a multimode single leg power converter which aims to enable cost effective power conversion, is modeled by small signal ac modeling approach. The proposed single-leg converter provides the same functionality of two independent converters (a main boost converter plus a single-leg bidirectional converter). Therefore, the proposed multimode single-leg converter can maximize the cost efficiency and ease maintenance and diagnostics since the circuit structure is simpler compared to the conventional approach utilizing two independent converters.

2.Conventional Structure Of The Boost And Bi-Directional Converter

Fig. 1 illustrates the typical circuit structure of a power conversion system for the battery or the UC, which consists of a boost converter and a bidirectional dc/dc converter. The power from an alternator or an energy source is converted toward the dc bus and stored to the battery or UC when their state of charge (SOC) is low. The boost converter boosts an input voltage to a bus voltage, and the bidirectional dc/dc converter charges/discharges the battery or the UC from the bus voltage.

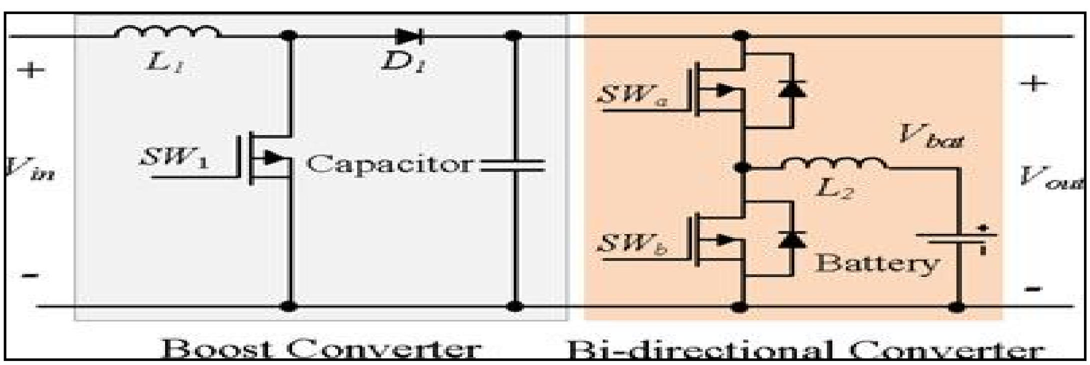


Figure 1: Typical circuit structure of a boost converter and a bidirectional dc/dc converter

3.Proposed Multimode Single-Leg Power Conversion System

The proposed circuit structure is illustrated in Fig. 2. Unlike the conventional configuration, the proposed structure has no boost converter (SW1switch is eliminated) and the D1diode location shown in Fig. 1 is moved utilizing the proposed multimode single-leg converter, which includes two switches (SWa,SWb), inductors (L1, L2) and a diode (D1). The multimode single-leg converter realizes the boost converter and the bidirectional dc/dc converter operations simultaneously. It means that a power switch SW1, a driver circuit, and a PWM port can be reduced, providing the same functionalities and power conversion. The proposed converter can boost the input voltage up, and charge/discharge storage devices such as batteries and UC at the same time.

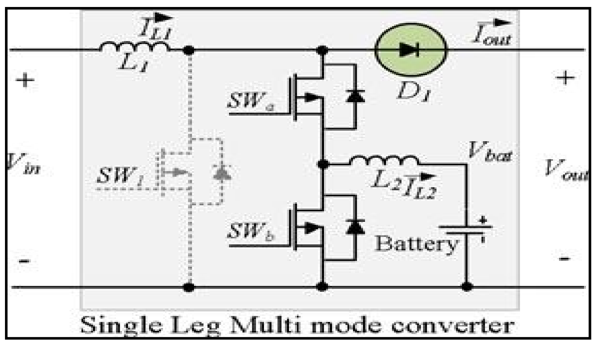


Figure 2: Circuit Configuration Of The Proposed Multimode Single-Leg Converter

4.Operation

In this paper, the functions of the proposed converter are categorized and analyzed based on four different modes: mode 1—main boost mode; mode 2—boost and buck mode; mode 3—boost and boost mode, and mode 4—battery boost mode.

4.1.Main Boost Mode

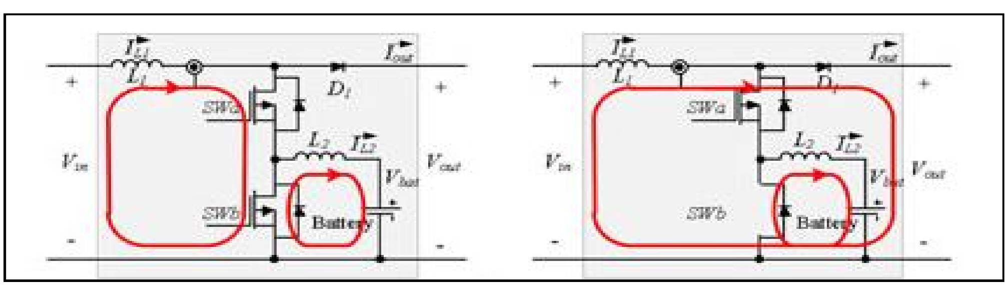


Figure 3: Main boost mode. (a) Control scheme and PWM patterns. (b) Currentflows during Ton(Left) and Toff(Right)

The purpose of this mode is to boost an input voltage Vinto an output voltage Vout

Ton

$$L_1 \frac{di_{L1}}{dt} = \mathrm{Vg(t)}$$

$$L_2 \frac{di_{L2}}{dt} = \mathrm{Vb}$$

Toff

$$L_1 \frac{di_{L1}}{dt} = \mathrm{Vg(t)} - \mathrm{V(t)}$$

$$L_2 \frac{di_{L2}}{dt} = \mathrm{Vb}$$

Adding perturbances we get

$$L_1 \frac{di_{L1}}{dt} = d\mathrm{(t)[Vg(t)]} + \mathrm{d'(t)[Vg(t)} - \mathrm{V(t)]}$$

$$L_2 \frac{di_{L2}}{dt} = d\mathrm{(t)[Vb]} + \mathrm{d'(t)[Vb]}$$

Averaging and linearizing, the equation for L1 and L2 in main boost mode is

$$L_1 \frac{di_{L1}}{dt} = \hat{V}\, g(\mathrm{t}) - D'\hat{v}(\mathrm{t}) + \hat{d}(\mathrm{t})V(\mathrm{t})$$

$$L_2 \frac{di_{L2}}{dt} = \hat{V}\, b(\mathrm{t})$$

4.2.Boost-Buck Mode

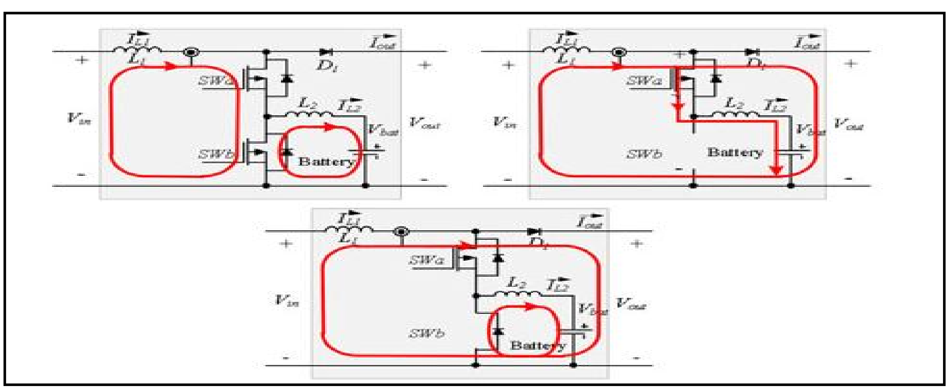


Figure 4: Boost and buck mode. (a) Control of boost and buck mode and PWMpatterns. Current flows during Ton boost (Up Left), Ton buck (Up Right), andToff buck (Bottom).

In this mode, the multimode single-leg converter operates as a boost converter and a buck converter at the same time

Ton-boost

$$L_1 \frac{di_{L1}}{dt} = Vg(t)$$

$$L_2 \frac{di_{L2}}{dt} = -Vb(\mathrm{t})$$

Ton-buck

$$L_1 \frac{di_{L1}}{dt} = Vg(t) - \mathrm{V}(\mathrm{t})$$

$$L_2 \frac{di_{L2}}{dt} = V(\mathrm{t}) - Vb(\mathrm{t})$$

Toff-buck

$$L_1 \frac{di_{L1}}{dt} = Vg(t) - \mathrm{V}(\mathrm{t})$$

$$L_2 \frac{di_{L2}}{dt} = Vb(\mathrm{t})$$

Adding perturbances we get

$$L_1 \frac{di_{L1}}{dt} = d(\mathrm{t})[Vg(t)] + \mathrm{d'(t)[Vg(t)} - \mathrm{V(t)]}$$

$$L_2 \frac{di_{L2}}{dt} = d(\mathrm{t})[-Vb(\mathrm{t})] + \mathrm{d'(t)[V(t)} - \mathrm{Vb]}$$

Averaging and linearizing, the equation for L1 and L2 in boost-buck mode is

$$L_1 \frac{di_{L1}}{dt} = \hat{V} g(t) - \mathrm{D'}\hat{v}(\mathrm{t}) + \hat{d}(\mathrm{t})V(\mathrm{t})$$

$$L_2 \frac{di_{L2}}{dt} = \hat{V} b(\mathrm{t}) + D'\hat{v}(\mathrm{t}) - \hat{d}(\mathrm{t})V(\mathrm{t})$$

4.3.Boost-Boost Mode

The purpose of boost-boost mode is to discharge from the battery and to boost voltage from Vin.It means that the multimode single-leg converter operates as two boost converters.

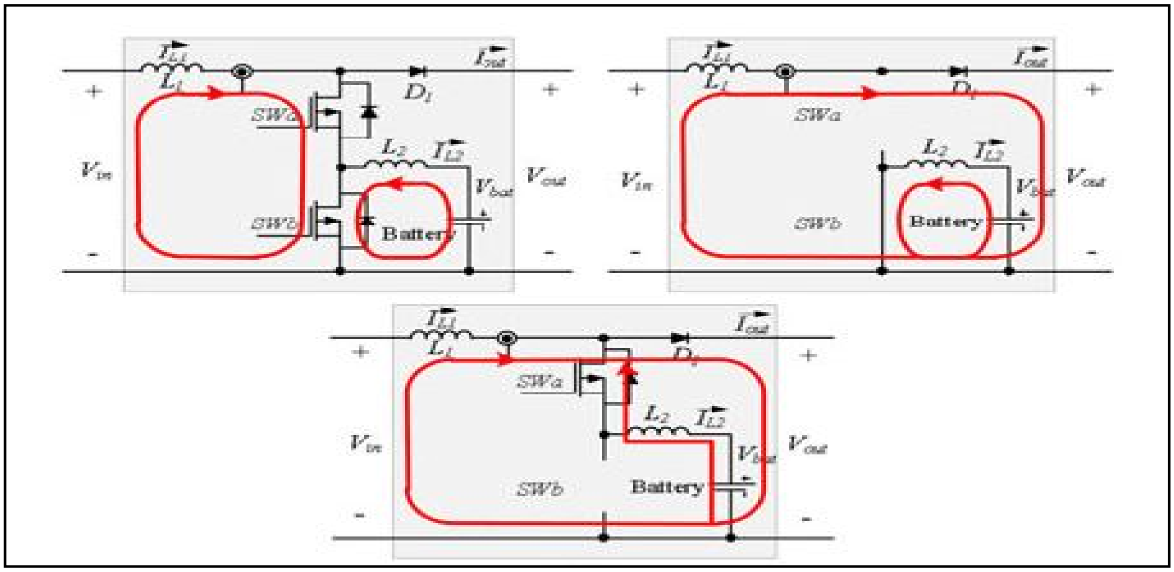


Figure 5: Boost and Boost mode. (a) Control of boost and boost mode and PWM patterns. (b) Current flows during Ton boost1 (Left), Ton boost2 − Ton boost1(Middle), and Toff boost2 (Right)

Ton-boost1

$$L_1 \frac{d i_{L1}}{dt} = Vg(\mathrm{t})$$

$$L_2 \frac{d i_{L2}}{dt} = -Vb$$

Ton-boost2-Ton-boost1

$$L_1 \frac{di_{L1}}{dt} = Vg(\mathrm{t}) - \mathrm{V}(\mathrm{t})$$

$$L_2 \frac{di_{L2}}{dt} = -Vb$$

Toff-boost2

$$L_1 \frac{di_{L1}}{dt} = Vg(\mathrm{t}) - \mathrm{V}(\mathrm{t})$$

$$L_2 \frac{di_{L2}}{dt} = V(\mathrm{t}) - \mathrm{Vb}$$

Adding perturbances we get

$$L_1\frac{di_{L1}}{dt}=d(t)Vg(t)+d'(t)[Vg(t)-V(t)]$$

$$L_2\frac{di_{L2}}{dt}=d(t)[-Vb]+d'(t)[-V(t)]$$

Averaging and linearising, the equation for L1 and L2 in boost-boost mode is

$$L_1\frac{di_{L1}}{dt}=\hat{V}g(t)-D'\hat{v}(t)+\hat{d}(t)V(t)$$

$$L_2\frac{di_{L2}}{dt}=D'\hat{v}(t)-D\hat{V}b(t)$$

4.4.Battery Boost Mode

The battery boost mode is for the case of a very low inputpower generation or input faults. When the input power is verylow, the system is not able to supply the energy to loads. Therefore,the total required energy must be supplied from the battery.

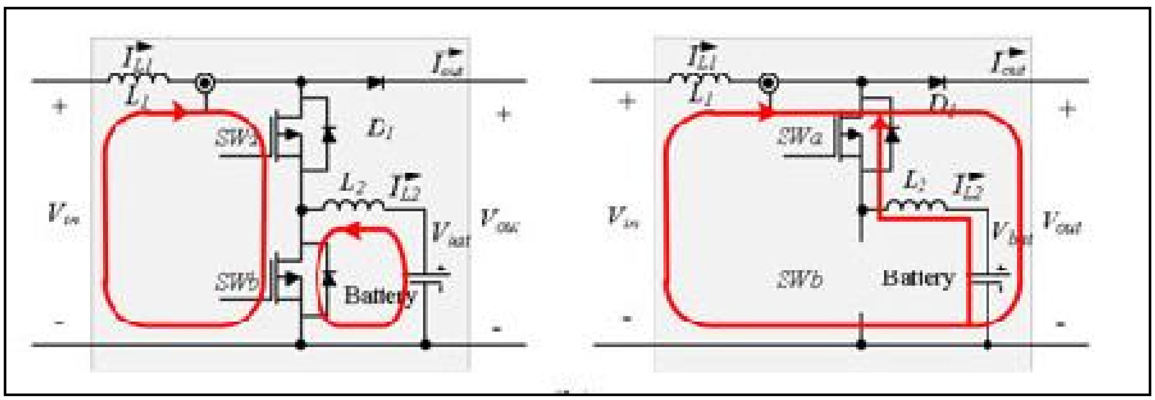


Figure 6: Battery boost mode. (a) Control of the battery boost mode and PWMpatterns. (b) Current flows during Ton (Left) and Toff (Right).

Ton

$$L_1\frac{di_{L1}}{dt}=Vg(t)$$

$$L_2\frac{di_{L2}}{dt}=-Vb$$

Toff

$$L_1\frac{di_{L1}}{dt} = \mathrm{Vg(t)} - V(\mathrm{t})$$

$$L_2\frac{di_{L2}}{dt} = \mathrm{Vb} - \mathrm{V(t)}$$

Adding perturbances we get

$$L_1\frac{di_{L1}}{dt} = d(\mathrm{t})Vg(\mathrm{t}) + \mathrm{d'(t)}[\mathrm{Vg(t)} - V(\mathrm{t})]$$

$$L_2\frac{di_{L2}}{dt} = d(\mathrm{t})[-\mathrm{Vb}] + \mathrm{d'(t)}[\mathrm{Vb} - \mathrm{V(t)}]$$

Averaging and linearising, the equation for L1 and L2 in boost-boost mode is

$$L_1\frac{di_{L1}}{dt} = \hat{V}g(\mathrm{t}) - D'\hat{v}(\mathrm{t}) + \hat{d}(\mathrm{t})V(\mathrm{t})$$

$$L_2\frac{di_{L2}}{dt} = -D\hat{V}\mathrm{b(t)} - \hat{d}(\mathrm{t})\mathrm{Vb} + \mathrm{D'}\hat{V}\mathrm{b(t)} - \mathrm{D'}\hat{v}(\mathrm{t}) - \hat{d}(\mathrm{t})\mathrm{Vb} + \hat{d}(\mathrm{t})\,\mathrm{V(t)}$$

Considering all the modes the equations corresponding to inductors L1 and L2 are

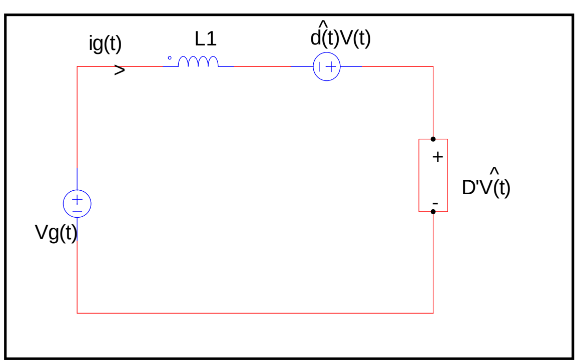
$$L_1\frac{di_{L1}}{dt} = \hat{V}\,g(\mathrm{t}) - D'\hat{v}(\mathrm{t}) + \hat{d}(\mathrm{t})\,\mathrm{V(t)}$$

$$L_2\frac{di_{L2}}{dt} = (1 - D)\hat{V}\mathrm{b(t)} - \hat{d}(\mathrm{t})\,\mathrm{Vb} + \mathrm{D'}[\hat{V}\mathrm{b(t)} + \hat{v}(\mathrm{t})]$$

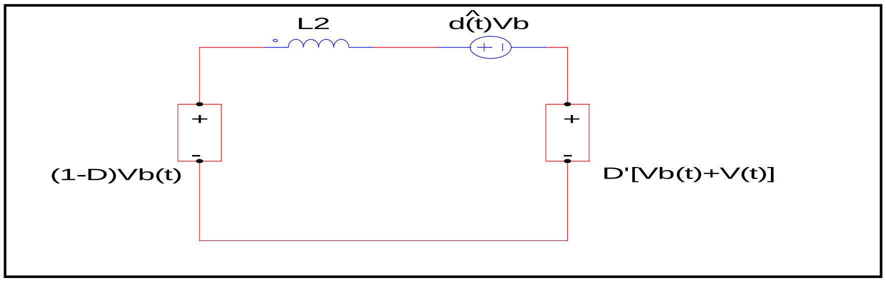
5.Circuit Modeling

The equivalent circuit corresponding to i/p side:

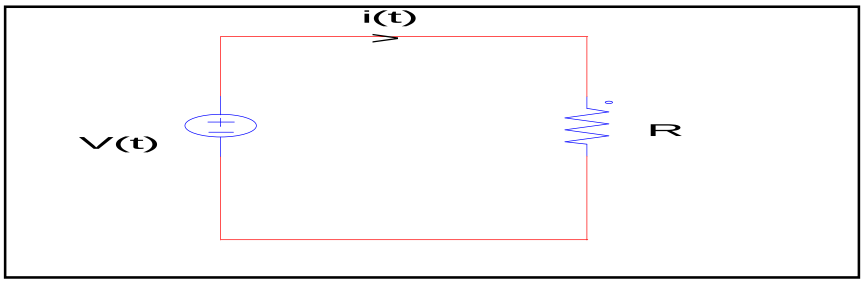
Inductor L1



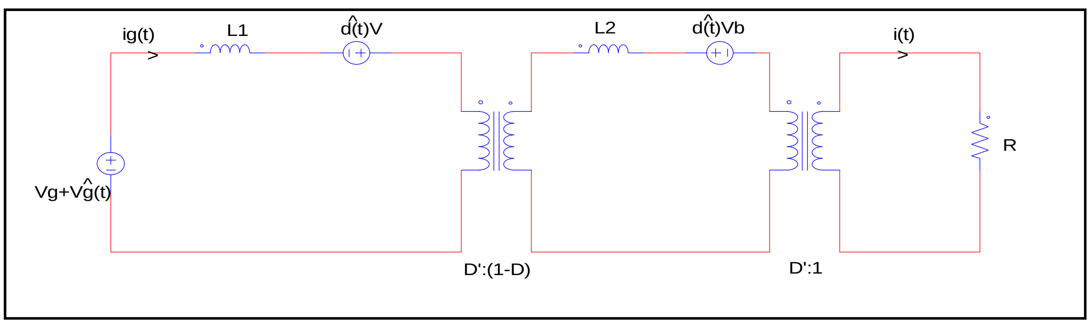
Inductor L2



The equivalent circuit corresponding to o/p side:



Small signal AC equivalent circuit



6.Conclusion

In this paper, the small signal ac modeling of a new multimode single-leg converter topology is proposed. It reduces the number of switching elements and hence the cost efficiency is maximized. The proposed converter has four different operational modes. And it enables two multimode functions which replace two independent converters (boost converter + bidirectional dc/dc converter). The proposed converter can be applied to a variety of energy conversion applications.

7.Reference

1. Taesik Park, Member, IEEE, and Taehyung Kim, Senior Member, IEEE Novel Energy Conversion System Based on a Multimode Single-Leg Power Converter pp. 213-220 IEEE transactions on power electronics, vol. 28, no. 1, january 2013
2. Hamid R. Karshenas1,2, Hamid Daneshpajooh2, Alireza Safaee2, Praveen Jain2 and Alireza Bakhshai2 1Department of Elec. & Computer Eng., Queen's University, Kingston, 2Isfahan University of Tech., Isfahan, 1Canada 2Iran Bidirectional DC-DC Converters for Energy Storage Systems
3. R. W. Erickson Fundamentals of Power Electronics, Edition I, New York: Chapman and Hall, May 1997.
4. Ke Jin, Member, IEEE, XinboRuan, Senior Member, IEEE, Mengxiong Yang, and Min Xu Power Management for Fuel-Cell Power System Cold Start pp.2391-2395 IEEE transactions on power electronics, vol. 24, no. 10, october 2009
5. Yan-Fei Liu, Senior Member, IEEE, Eric Meyer, Student Member, IEEE, and Xiaodong Liu Recent Developments in Digital Control Strategies for DC/DC Switching Power Converters pp.2567-2577 IEEE transactions on power electronics, vol. 24, no. 11, november 2009