IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

DESIGN AND SIMULATION OF PHASE SHIFTED DC-DC FULL BRIDGE CONVERTER

To cite this article: Prarthiv Evan Poudyal *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **623** 012021

DESIGN AND SIMULATION OF PHASE SHIFTED DC-DC FULL BRIDGE CONVERTER

Prarthiv Evan Poudyal[1], V Vigneshwar[1], N K Kumar[1], V Indragandhi[1], A Nazar Ali[2]

[1]School of Electrical Engineering, Vellore Institute of Technology, Vellore
[2]Associate Professor, Department of EEE, Rajalakshmi College of Technology, Chennai

Abstract -Electric and hybrid electric vehicle (EV/HEV) architectures require a small DC-DC converterto replace any conventional vehicle's alternator. The DC-DC converter, also described as the vehicle Auxiliary Power Module (APM), provides power flow between the vehicle high voltage (HV) and low voltage (LV) DC bus. This abstract represents the phase shifted full bridge DC-DC converter scheme to design, simulate DC/DC Converter for a power rating of 80W intended for low power/ auxiliary applications in electric vehicles The proposed converter is very beneficial as it can be used for 4 quadrant operation much adaptive to the unknown parameters in the PV system and these unknown parameters are estimated through the adaptation laws in the algorithm which guarantees maximum power extraction possible from the power converter for a PV system. The converter supplies AC current as per requirement. The overall stability of the converter output is analyzed by simulation. The results are compared with other existing converter results for improving power quality even further. The proposed results indicate the robustness of the proposed scheme.

Keywords: DC-DC Converter, Phase Shift Full Bridge, Hybrid vehicles.

1 INTRODUCTION

Electric vehicles (EVs) powered by batteries are the key to reducing global warming and rising fuel cost.[1,2] A recent survey reported that EVs must be a good for most Americans' driving and commute patterns, and 40% of the respondents indicated strong interests in purchasing EVs.

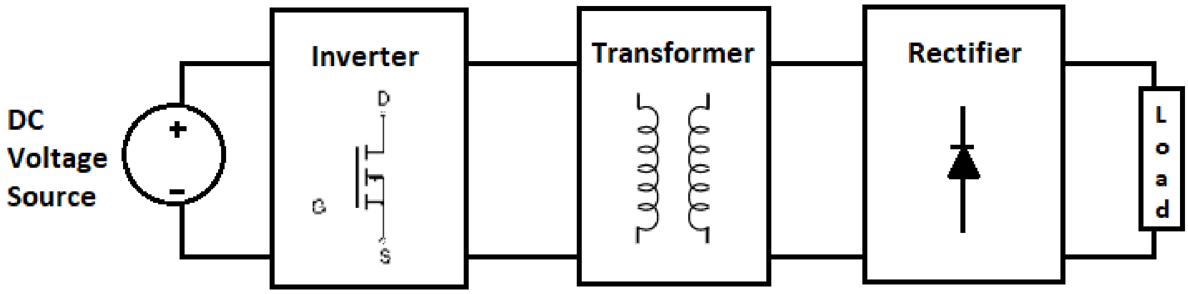
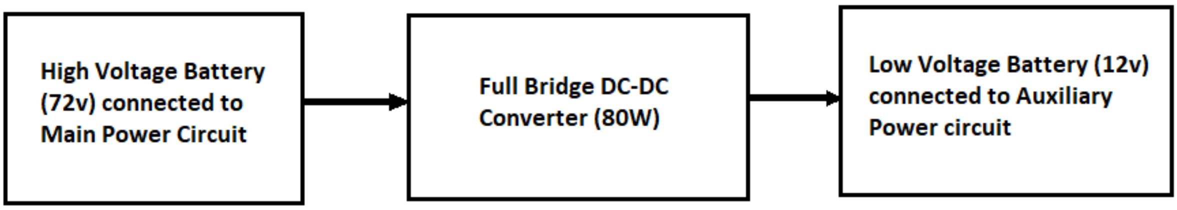


Figure 1 Isolated Topology

[2]Despite the increasing popularity of EVs, they have not yet dominated the internal combustion vehicle market for three reasons. First, EVs are expensive due mainly to the large number of battery cells required to power them. [3]There have been various ongoing researches about reducing EV energy consumption in the usage-phase that focuses on the vehicle side through, for an instance, optimization of the powertrain system, upgrade to motor control strategies, and improvements in power density of the battery. [5,7] Most of the modern-day electric cars struggle with range that they can provide to the user on a full charge of these batteries

The possible ways to tackle this can be two:

(1) Increase the capacity of the battery



(2) Decrease the loads and improve the converter efficiency within the car.

Figure.2 Block Diagram

[4]The second way, Decrease the loads and improve the converter efficiency within the car. Main Power Circuit (Motor and Drive Circuit). Auxiliary Power Circuit (Air Conditioning Unit, Audio System, GPS and others)

2. Non-isolated converters

The non-isolated type converters are generally used wherever the voltage needs to be either stepped up or down by a relatively small ratio (less than 4:1). [7,8,9] And whenever there is no problem with the output and input having no dielectric isolation. There are five main types of converter in this non-isolated group, usually called the buck, boost, buck-boost, [11,12] Cuk and charge-pump converters. The buck converter is used for stepping down the voltage to the desired value, while the boost converter is used for stepping up the voltage to the desired value. The buck-boost and Cuk converters can be used for either stepping-

IOP Conf. Series: Materials Science and Engineering **623** (2019) 012021 doi:10.1088/1757-899X/623/1/012021

down or stepping-up as per applications requirement. [13,14] The charge-pump converter is used for either voltage step-up or voltage inversion, but only in relatively low power applications.

3. Related Works

- **Mahindra e2o plus P8 Variant**

  Specifications:

  - High Voltage Battery = 72V
  - Low Voltage Battery = 12V
  - DC-DC Converter Topology = Full Bridge Phase Shifted
  - Power Rated (P_o) = 80W

- **Toyota Prius 2001 Hybrid Variant**

  Specifications:

  - High Voltage Battery = 300V
  - Low Voltage Battery = 42V
  - DC-DC Converter Topology = Full Bridge Isolated Boost
  - Power Rated (P_o) = 80W

4. SIMULATION&SYSTEM MODELLING

Designing of Transformer. Filter capacitor & Load resistance

$$Transformer\ Turns\ Ratio\ (N) = \frac{Output\ Voltage(V_o)}{Input\ Voltage\ (V_i)}$$

Here,

$$Output\ Voltage\ (V_o) = 12V,\ Input\ Voltage(V_i) = 72V$$

$$Transformer\ Turns\ Ratio\ (N) = \frac{V_o}{V_i}$$

$$Transformer\ Turns\ Ratio\ (N) = \frac{12}{72}$$

$$i.e,\ N = 1/6$$

$$Load\ Resistance\ (R) = \frac{[Output\ Voltage\ (V_o)]^2}{Ouput\ Power\ (P_o)}$$

Here,

$$Output\ Voltage\ (V_o) = 12V, Ouput\ Power\ (P_o) = 80W$$

IOP Conf. Series: Materials Science and Engineering **623** (2019) 012021 doi:10.1088/1757-899X/623/1/012021

$$Load\ Resistance\ (R) = \frac{[12]^2}{80}$$

$$i.e, R = 1.8\Omega$$

$$Filter\ Capacitor\ (CF) = \frac{1}{4fR}\left[1 + \frac{1}{\sqrt{2} \times \overline{RF}}\right]$$

Here,

$$Ripple\ Factor\ (\overline{RF}) = \frac{Ripple\ Voltage\ (V_r)}{Average\ Output\ Voltage\ (V_o)}$$

Here,

$$Frequency(f) = 100kHz,\ Load\ Resistance(R) = 1.8\Omega,$$

$$Ripple\ Voltage(V_r) = 0.12V,\ Average\ Output\ Voltage\ (V_o) = 12V$$

$$Ripple\ Factor\ (\overline{RF}) = \frac{0.12}{12} = 0.01$$

$$Filter\ Capacitor\ (CF) = \frac{1}{4fR}\left[1 + \frac{1}{\sqrt{2} \times \overline{RF}}\right]$$

$$= \frac{1}{4 \times 100 \times 10^3 \times 1.8}\left[1 + \frac{1}{\sqrt{2} \times 0.01}\right]$$

$$i.e,\ CF = 100\mu F$$

5. SPECIFICATION FOR MATLAB MODELLING.

Input Voltage (V_i)= 72V

Output Voltage (V_o) = 12V

Power Rated (P_o) = 80W

Transformer Turns Ratio ($P:S_1:S_2$) = 6:1:1

Duty Cycle = 50%

Topology = Full Bridge Phase Shift Type

Output Filter Capacitor (CF) = 100µF

Load Resistance (R) = 1.8Ω

5.1 Steady State Results:

Input Voltage (V_i)= 72V

Input Current (I_i) = 1.21A

Input Power (P_i) = 87.12W

Output Voltage (V_o)= 12V

IOP Conf. Series: Materials Science and Engineering **623** (2019) 012021 doi:10.1088/1757-899X/623/1/012021

Output Current (I_o) = 6.69

Output Power (P_o) = 80.28W

Hence, we simulate a DC/DC Converter for a power rating of 80W intended for low power applications in hybrid electric vehicles.

6. OPERATION

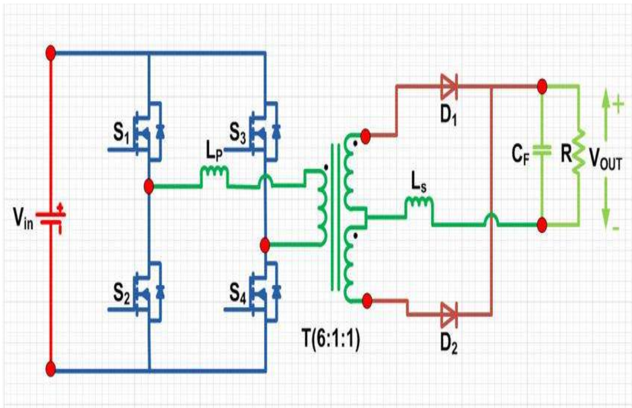


Figure.3 Circuit Diagram

A full bridge isolated phase shifted DC-DC converter is used. Full bridge refers to turning ON the switch by pairing on two of the four switches (MOSFET) crossing diagonally to transfer electric power from primary side to secondary side. Efficiency is improved with the phase shift type using soft switching. We assume the breakdown voltage required for MOSFET with the full bridge converter to be:

When S_1 & S_4 are turned ON, ON-resistance of MOSFET is low and as a result, it can be regarded as a short circuit between drain and the source. Therefore, the voltage V_{in} is applied between the drain and the source of MOSFET, S_2 & S_3 are in the OFF state. When S_2 & S_3 are turned ON, V_{in} is also applied to S_1 & S_4 that are in the OFF state. This is the measure of the breakdown voltage required for MOSFET. In fact, a design with sufficient margin is required with surge voltage and derating taken into consideration. Voltages of $+V_{in}$ & $-V_{in}$ are applied to the primary side of the transformer alternately by switching the switches. This enables an effect equivalent to that of applying the power supply voltage twice (V_{in} * 2) which allows supporting high power application. A device with high speed and low ON resistance is required as a switching element. POWER MOSFET enables this demand. There is some loss in MOSFET because of the flow of drain current Id under the application of voltage between drain and the source. During switching transient period of MOSFET, drain current I_d flows with voltage applied V_{ds}, causing a loss. Hence, soft-switching is used, switching when the current or voltage is zero, it is a counter measure for the switching loss. A method to switch during zero voltage is called ZVS and that with zero current is called ZCS. However, ZVS is more popular in the full bridge type power supply circuit using MOSFETs.

6.1 PHASE SHIFTED TYPE FULL BRIDGE MODE 1 OPERATION

The timing to control each MOSFET differs. Timing is divided into 8 segments. In addition, a dead time is applied while S_1 & S_2, and S_3 & S_4 (vertically connected switches) are NOT turned ON simultaneously. Every MOSFET is turned OFF in the hard switch type, not every MOSFET is turned OFF in the phase shift type. From t_0 to t_1, When S_1 & S_4 are turned ON, V_{in} is applied positively to the dot end of the primary transformer. At this time, the dot end of the secondary side becomes positive and is turned ON by forward biasing the diode D_1. In addition, the capacitor C_o is charged via the choke coil L_s. t_1 to t_2, at the beginning of this period the voltage between the drain and the source is zero thus it starts with soft switching. It doesn't transit to OFF instantly. The freewheel current caused by the leakage inductance L_p continues to flow even during transition period, the charge voltage finally reaches equivalent to V_{in}.

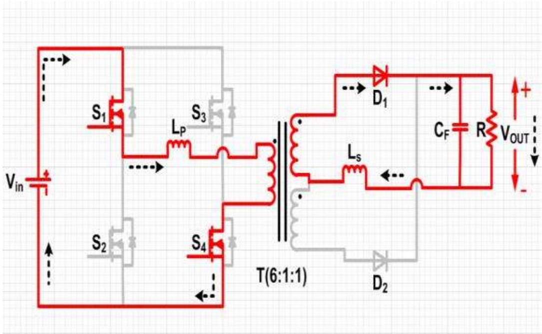


Figure 4. Mode 1 Operation

6.2 BRIDGE MODE 2 OPERATION

When S_2 & S_3 are turned ON, the voltage between the drain and source of Q_2 is zero, and during transition from OFF to ON, the freewheel current of L_p continues to flow, soft switching is completed. The non-dot side of both primary and secondary sides of the transformer becomes positive. D_2 is turned ON to charge C_o via choke coil L_s. electric power is transferred from primary to secondary side. Phase-shift type realizes soft switching by optimizing ON/OFF from S_1 through S_4.

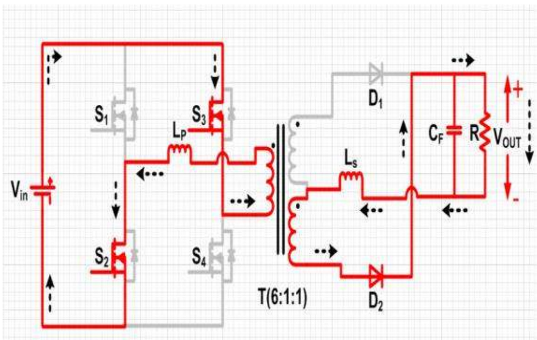
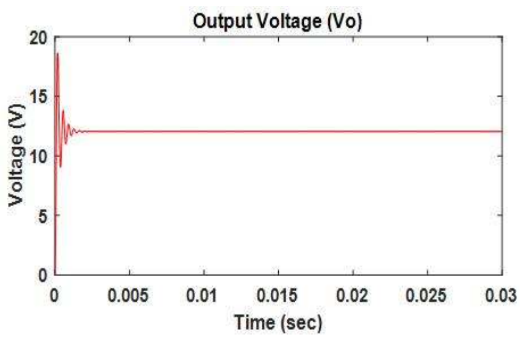
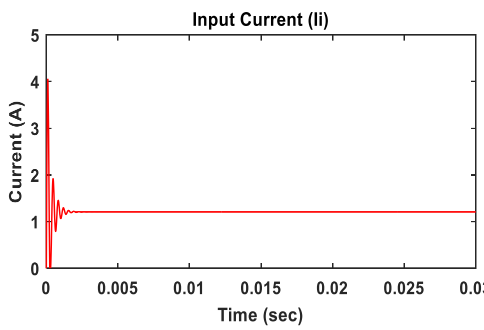


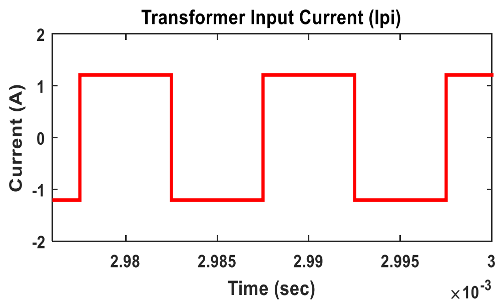
Figure 5. Mode 2 Operation

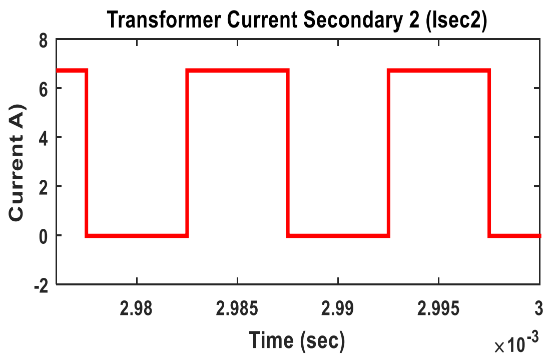
7. SIMULATION RESULTS

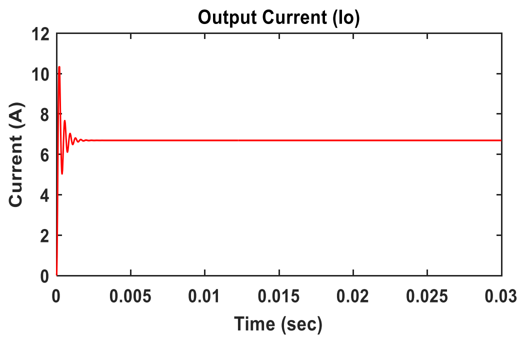


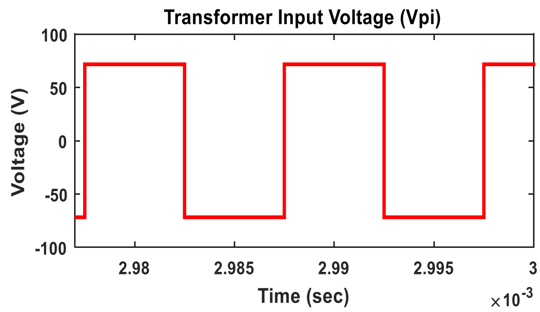


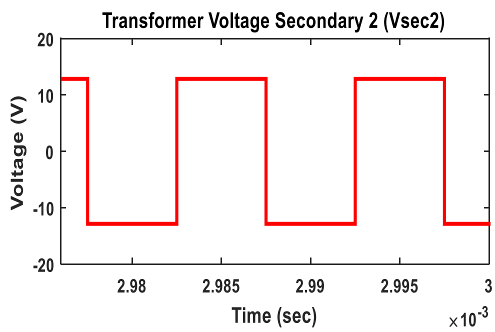
IOP Conf. Series: Materials Science and Engineering **623** (2019) 012021 doi:10.1088/1757-899X/623/1/012021

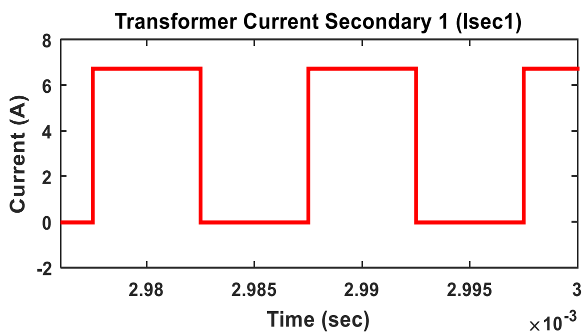


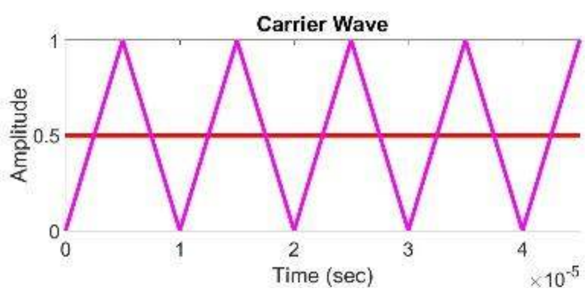


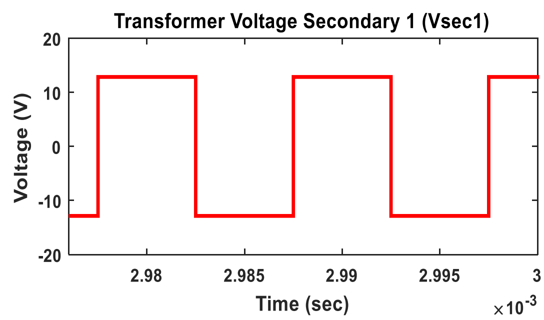


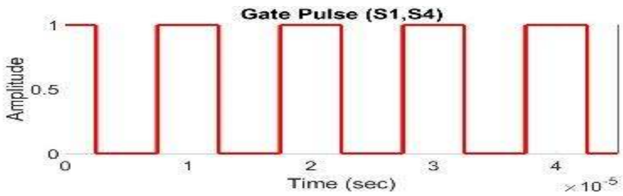


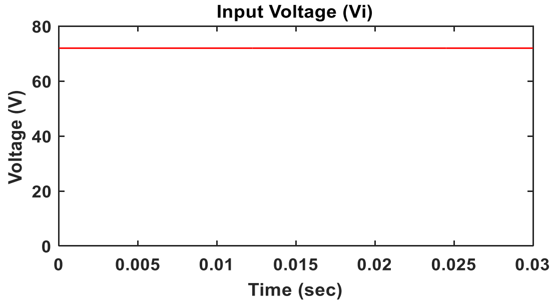












8. CONCLUSION

This paper proposes a new active soft switching circuit for the PSFB DC-DC converter. The converter's analysis is presented with the mathematical treatment required. The converter's equivalent steady-state circuit model and dynamic model are presented. The converter's design guidelines will be discussed. A design example is presented in accordance with the design guidelines. The designed converter is simulated and for the specifications a prototype is developed. In order to validate the analysis, the circuit simulations and experimental waveforms are presented. Experimental results are consistent with the theory and simulations. Converter efficiency has been improved overall. This model of proposed are validated experimentally.

9. REFERENCES

[1] K. Shi, D. Zhang, Z. Zhou, M. Zhang, D. Zhang and Y. Gu, “A Novel Phase-Shift Dual Full-Bridge Converter With Full Soft-Switching Range and Wide Conversion Range,” IEEE Transactions on Power Electronics, Vol. 31, No. 11, November 2016

[2] Mallikand A. Khaligh, “Variable-Switching-Frequency State-Feedback Control of a Phase-Shifted Full-Bridge DC/DC Converter,” IEEE Transactions on Power Electronics, Vol. 32, No. 8, August 2017

[3] O. Lee, “Hybrid DC-DC Converter with Phase-Shift or Frequency Modulation for NEV Battery Charger,” IEEE Transactions on Industrial Electronics, Vol. 63, No. 2, February 2016

[4] S. Kim, H. Cha, H. F. Ahmed, B. Choi, H. Kim, “ Isolated Double Step-down DC-DC Converter with Improved ZVS Range and No Transformer Saturation Problem ,” IEEE Transactions on Industrial Electronics, Vol. 32, No. 3, March 2017

[5] Y.Shen, X.Sun, W.Li, X.Wu, and B.Wang,“A Modified Dual Active Bridge Converter With Hybrid Phase-Shift Control for Wide Input Voltage Range,” IEEE Transactions on Power Electronics, Vol. 31, No. 10, October 2016

[6] J. Mason and P. K. Jain, "New Phase Shift Modulated ZVS Full Bridge DC/DC Converter with Minimized Auxiliary Current for Medium Power Fuel Cell Application," in Proc. Power Electronics Specialists Conference, 2005, pp. 244-249, June 2005.

[7] Y. Jang and M. M. Jovanovic, "A New Family of Full-Bridge ZVS Converter," IEEE Transactions on Power Electronics, vol. 19, no. 3, May 2004.

[8] Z. Chen, B. Ji, F. Ji, and 1. Shi, "Analysis and Design Considerations of An Improved ZVS Full-Bridge DC-DC Converter," in Proc. Applied Power Electronics Conference and Exposition, 2010, pp. 1471-1476.

[9] B. Yang, 1. 1. Duarte, W. Li, K. Yin, X. He, and Y. Deng, "Phase Shifted Full Bridge Converter Featuring ZVS over the Full Load Range," in Proc. 36th Annual Conference on IEEE industrial Electronics Society, 2010, pp. 644-649.

[10] X. Zhou, M. Donati, 1. Amoroso, and F. C. Lee, "Improved Light-Load Efficiency for Synchronous Rectifier Voltage Regulator Module," IEEE Transactions on Power Electronics, vol. 15, no. 5, May

2000.
[11] Texas Instruments, "Green Phase-Shifted Full-Bridge Controller with Synchronous Rectification," Datasheet SLUSAI6, Mar. 2010.
[12] R. Ramachandran and M. Nymand, “Design and analysis of an ultra-high efficiency phase shifted full bridge GaN converter,” in Proc. IEEE Applied Power Electronics Conference and Exposition, Charlotte, NC, Mar. 2015, pp. 2011-2016.
[13] B. Y. Chen and Y. S. Lai, “Novel Dual Mode Operation of Phase-Shifted Full Bridge Converter to Improve Efficiency under Light Load Condition,” in Proc. IEEE Energy Conversion Congress and Exposition, San Jose, CA, Sept. 2009, pp. 1367-1374.
[14] J.W. Kim, D.Y. Kim, C.E. Kim, M.Y. Kim et. al. “Switching control method for light load efficiency improvement in phase shifted full bridge converter,” in Proc. IEEE Energy Conversion Congress and Exposition Asia, Melbourne, Jun. 2013, pp. 165-169.