ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Special Issue 5, December 2014

Bidirectional Snubberless Commutated Soft-Switching DC/DC Converter for Fuel Cell Vehicles

Vaseem Faizal[1], Geetha B[2], Babu Paul[3]

P.G. Student, Mar Athanasius College of Engineering, Kothamangalam, Kerala, India [1]

Professor, Mar Athanasius College of Engineering, Kothamangalam, Kerala, India[2]

Assistant Professor, Mar Athanasius College of Engineering, Kothamangalam, Kerala, India[3]

ABSTRACT: A naturally clamped zero-current commutated soft switching bidirectional full-bridge isolated dc/dc converter is implemented by eliminating the necessity for passive snubbers. Switching losses are reduced significantly owing to zero-current switching of primary side devices and zero-voltage switching of secondary-side devices. Soft switching and voltage clamping are inherent and load independent. The voltage across primary-side devices is independent of duty cycle with varying input voltage and output power and clamped at rather low reflected output voltage, enabling the use of semiconductor devices of low voltage rating. These merits make the converter promising for fuel cell vehicles application, front-end dc/dc power conversion for fuel cell inverters, and energy storage in the DC/DC converter is analysed with zero current Commutation (ZCC) and the natural voltage clamping (NVC) has been analysed. Experiment simulated using MATLAB 2010.Ra and output power of 500W is obtained which is suitable for low power automotive ac motor.

KEYWORDS: ZCS(zero current switching), ZVS(zero voltage switching), ZCC(zero current commutation), NVC(nominal voltage clamping).

I. INTRODUCTION

In automotive industry most research takes place in the electric vehicles. Two major concepts are electric vehicles(EV) and fuel cell vehicles(FCV). Comparing with EV's, FCV's has clear upper hand as FCV need short charging period and greater range of driving. In the FCV itself, earlier implementation was using voltage fed converter but it has lot disadvantages such as high input pulsating current, limited soft-switching range, high circulating current through switches and relatively low efficiency for high voltage amplifications and high current input applications. Because of the draw backs of voltage fed based converter, the later converter based on current source had been implemented using snubbers. Usually employed current fed converters were resistor-capacitor-diode(RCD) snubber. But RCD snubber leads to low efficiency owing to clamping energy dissipated in snubber resistor. As a result a novel current fed DC/DC converter is proposed.

II. PROPOSED TOPOLOGY

A dual half-bridge bidirectional dc/dc converter is proposed as shown in fig.1. However, this topology requires four split capacitors that occupy a considerable volume of the converter. It may need an additional control to avoid any voltage imbalance across the capacitors. In addition, the topology is not modular and is not easily scalable for higher power. Peak currents through the primary switches are greater than2.5× the input current and the top and bottom switches share unequal currents.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Special Issue 5, December 2014

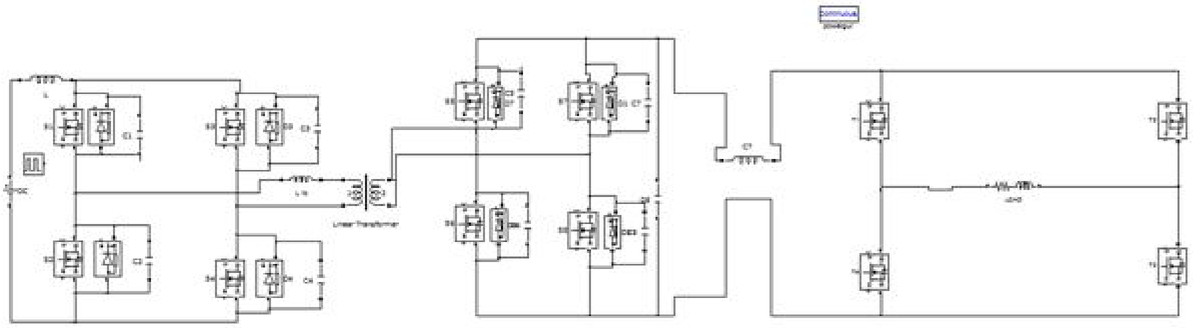


Fig. 1. Circuit Diagram of proposed system

Mainly four methods are used here to reduce the switching losses. ZVS, ZCS, ZCC, NVC, ZCS method is used in the primary switches, when current becomes zero in the switches gate signal is switches to zero, and voltage start to build up. ZVS is used in the secondary switches, when voltage across the switch becomes zero gate signal is switched to high, so that current start to increase. Before turning off the diagonal switch pairs of primary side switches (S_1-S_4), the other pair (S_2-S_3) is turned on. It diverts current from one switch pair to the other, causing the current through the conducting switch pair to rise and the current through conducting switch pair to fall to zero naturally resulting in ZCC. Later the body diodes across switching pairs to start conducting and their gating signals are removed leading to ZCS turnoff of the devices. Commutated device capacitance starts charging with NVC.

III. PRINCIPLE OF OPERATION

A. *Principle of operation*

Principle of operation is explained with the help of 8 modes as given below.

1) *Mode1*

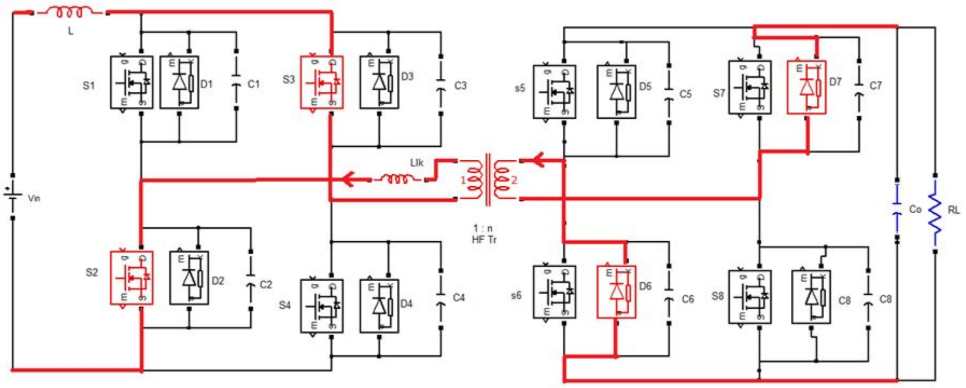


Fig. 2. Mode 1

In this interval, primary-side H-bridge switches S_2 and S_3 and antiparallel body diodes D_6 and D_7 of secondary-side H-bridge switches are conducting. The current through inductor $L_{lk}$is negative and constant. Power is transferred to the load through the HF transformer. Non-conducting secondary devices S_5 and S_8 are blocking output voltage V_o, and non-conducting primary devices S_1 and S_4 are blocking reflected output voltage V_o/n. The values of current through various components are

$$i_{S2} = iS3 = I\text{in},\ iS1 = iS4 = 0,\ i\text{lk} = -I\text{in},\ \text{and}\ iD6 = iD7 = I\text{in}/n \qquad (1)$$

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Special Issue 5, December 2014

2) Mode 2

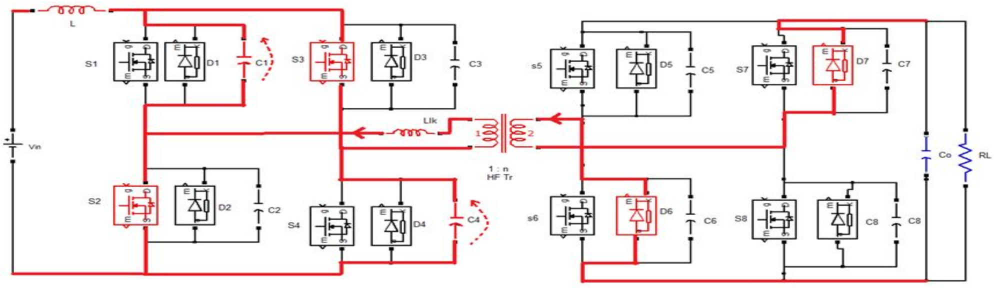


Fig.3. Mode 2

At $t = t_1$, primary switches S_1 and S_4 are turned on. Snubber capacitors C_1 and C_4 discharge in a very short period of time.

3) Mode 3

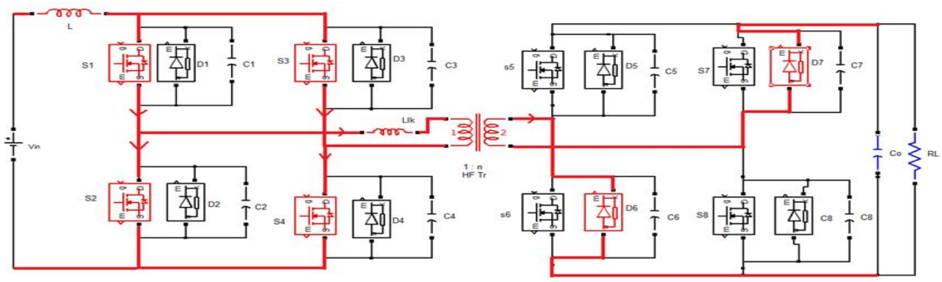


Fig.4. Mode 3

Now, all four primary switches are conducting. Reflected output voltage V_o/n appears across leakage inductance $L_{lk}$and causes its current to increase linearly. It causes currents through previously conducting devices S_2 and S_3 to reduce linearly. It results in conduction of switches S_1 and S_4 that started conducting with zero current, which helps reduce associated turn-on loss. Since the antiparallel body diodes D_6 and D_7 are conducting, switches S_6 and S_7 can be gated for ZVS turn-on. At the end of this interval $t = t_3$, D_6 and D_7 commutate naturally. Primary current reaches zero and ready to change polarity. Current through all primary devices reaches $I_{in}/2$. Final values are

$i_{S1} = i_{S2} = i_{S3} = i_{S4} = I_{in}/2$, and $i_{D6} = i_{D7} = 0 i_{lk} = 0$ (2)

4) Mode 4

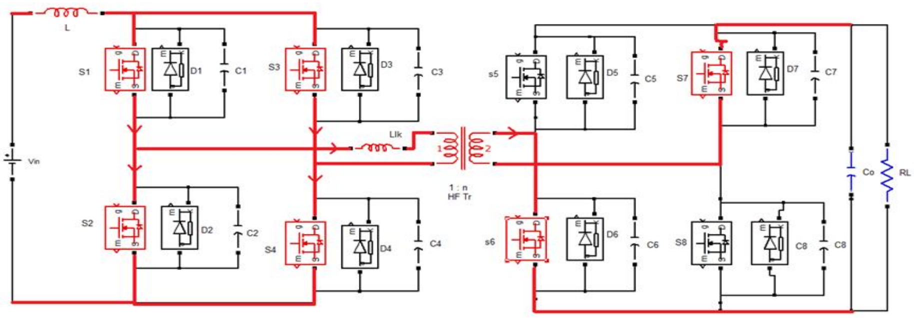


Fig.5.Mode 4

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Special Issue 5, December 2014

In this interval, secondary H-bridge devices S_6 and S_7 are turned on with ZVS. Currents through all the switching devices continue increasing or decreasing with the same slope as in interval 3. At the end of this interval, primary devices S_2 and S_3 commutate naturally with ZCC and their respective currents i_{S2} and i_{S3} reach zero obtaining ZCS. The full current, i.e., input current I_{in}, is taken over by other devices S_1 and $S_4$and the transformer current changes polarity. Final values are

$i_{lk}= I_{in}$, $i_{S1} = i_{S4} = I_{in}$, $i_{S2} = i_{S3} = 0$, and $Is6 = iS7 = Iin/n$. (3)

5) *Mode 5*

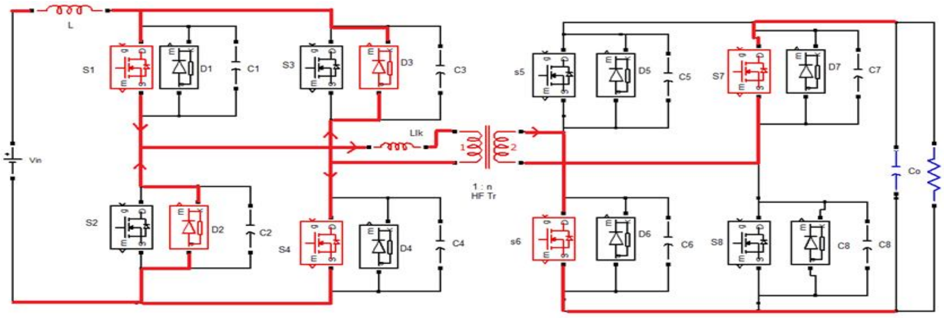


Fig.6 .Mode 5

In this interval, the primary current or leakage inductance current i_{lk} further increases with the same slope. Antiparallel body diodes D_2 and D_3 start conducting, causing extended zero voltage to appear across the outgoing or commutated switches S_2 and $S_3$to ensure ZCS turnoff. Now, secondary devices S_6 and S_7 are turned off. At the end of this interval, currents through the transformer and switches S_1 and S_4 reach their peak value. This interval should be very short to limit the peak current through the transformer and switches, and thus their kilovolt ampere ratings.

6) *Mode 6*

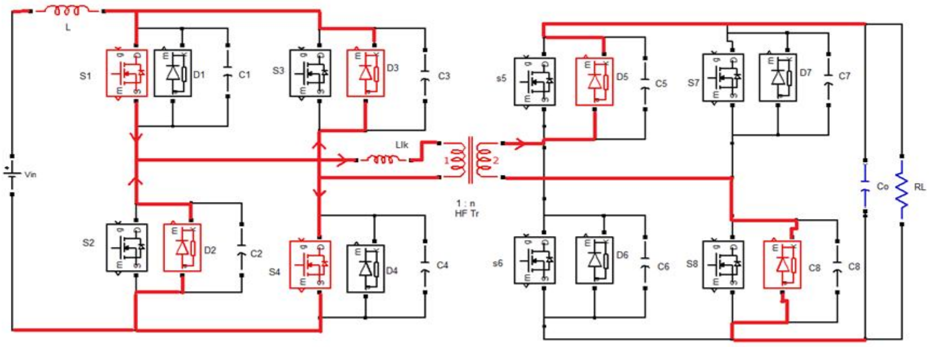


Fig.7. Mode 6

During this interval, secondary switches S_6 and S_7 are turned off. Antiparallel body diodes of switches S_5 and S_8 take over the current immediately. Therefore, the voltage across the transformer primary reverses polarity and the current through it starts decreasing. The currents through switches S_1 and S_4 and body diodes D_2 and D_3 also start decreasing.At the end of this interval, currents through D_2 and D_3 reduce to zero and are commutated naturally. Currents through S_1 and S_4 and the transformer reach I_{in}.Final values are

$i_{lk}= i_{S1} = i_{S4} = I_{in}$, $i_{D2} = i_{D3} = 0$, and $iD5 = iD8 = Iin/n$. (4)

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Special Issue 5, December 2014

7) *Mode 7*

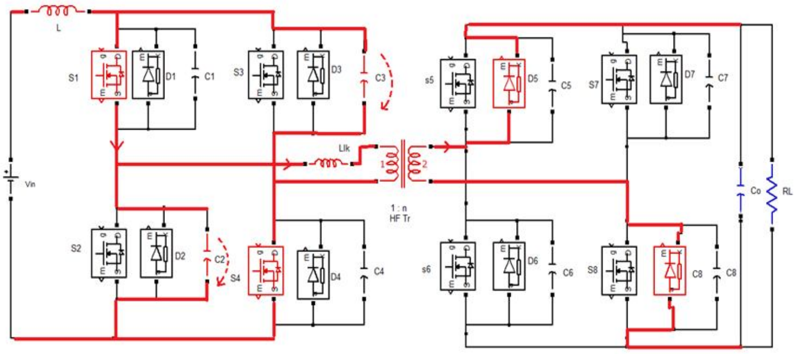


Fig.8. Mode 7

In this interval, snubber capacitors C_2 and C_3 charge to V_o/n in a short period of time. Switches S_2 and S_3 are in forward blocking mode now.

8) Mode 8

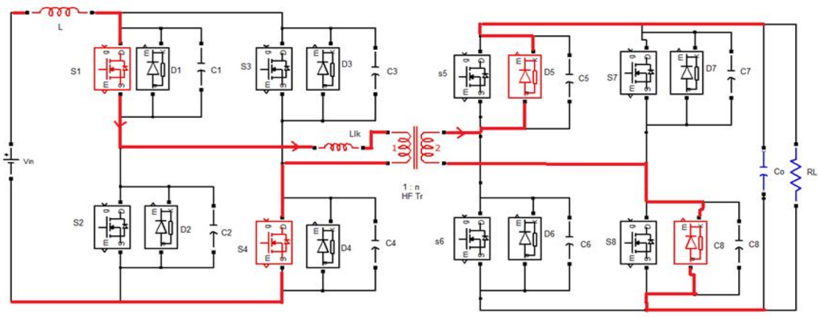


Fig.9 Mode 8

In this interval, currents through S_1 and S_4 and the transformer are constant at input current I_{in}. The current through antiparallel body diodes of the secondary switches D_5 and D_8 is I_{in}/n. The final values are

$$iS1 = iS_4 = ilk = Iin,\ iS_2 = iS_3 = 0,\ \text{and}\ iD_5 = iD_8 = I_{in}/n. \quad (5)$$

In this half HF cycle, current has transferred from one diagonal switch pair to the other diagonal switch pair, and the transformer current has reversed its polarity.

DC voltage obtained at the terminals of a convertr is inverted to AC with the help of single phase full bridge inverter as shown in the figure.

IV. SIMULINK MODEL.

A. *Simulink Model*

In the belowSimulink model, a dc /dc converter and dc/ac converter are combined. In the operation of dc/dc converter shoot through of switches are implemented which helps to enhance the energy in the inductor. Value of transfer inductance is calculated.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Special Issue 5, December 2014

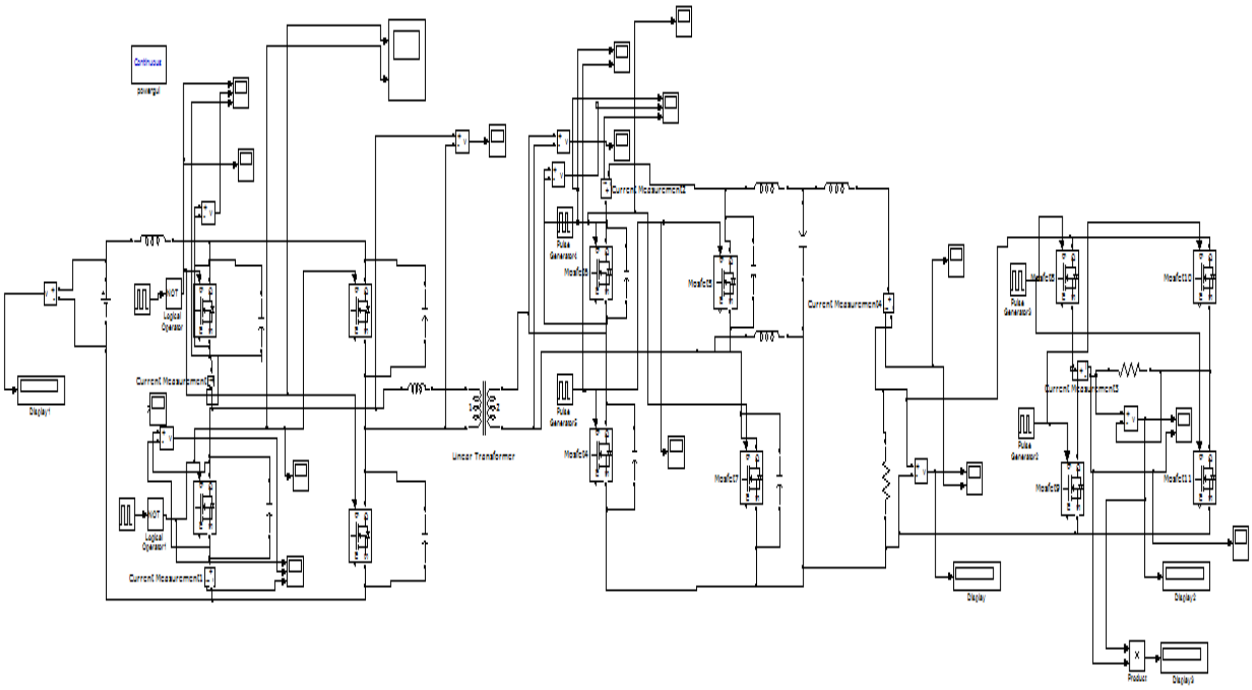


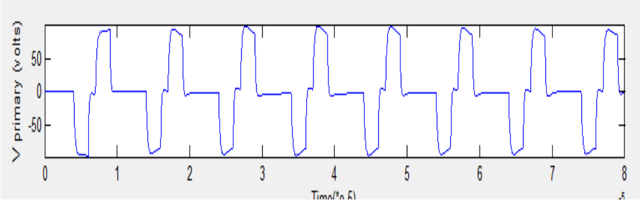
Fig.11. Simulink model of proposed system with feedback.

B.Simulation parameter

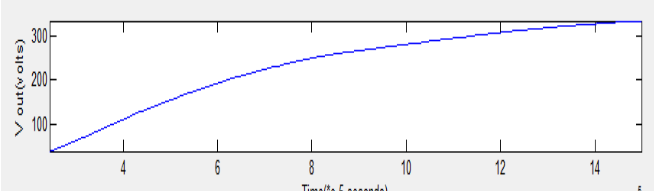
a) Input voltage : 100 V DC
b) Input inductor : 1e-9 H
c) C1, C2,................C8 : 1e-6 F
d) Transfer inductance, Llk: 1.5e-6 H
e) Load resistance : 100 ohm
f) Frequency : 50 KHz

V. SIMULATION RESULTS

Simulation result of the converter is shown below. Input voltage of 100v is applied, and get an output voltage of 316 v. AC volttage is obtained in the primary of the transformer as shown below, which is converted to DC and boosted up with the help of switching. This DC voltage is converted to AC by single pahse full bridge inverter. An output power of 500w is obtained which makes it suitable to use an auxiliary source of energy in the FCV's.



(a)



(b)

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Special Issue 5, December 2014

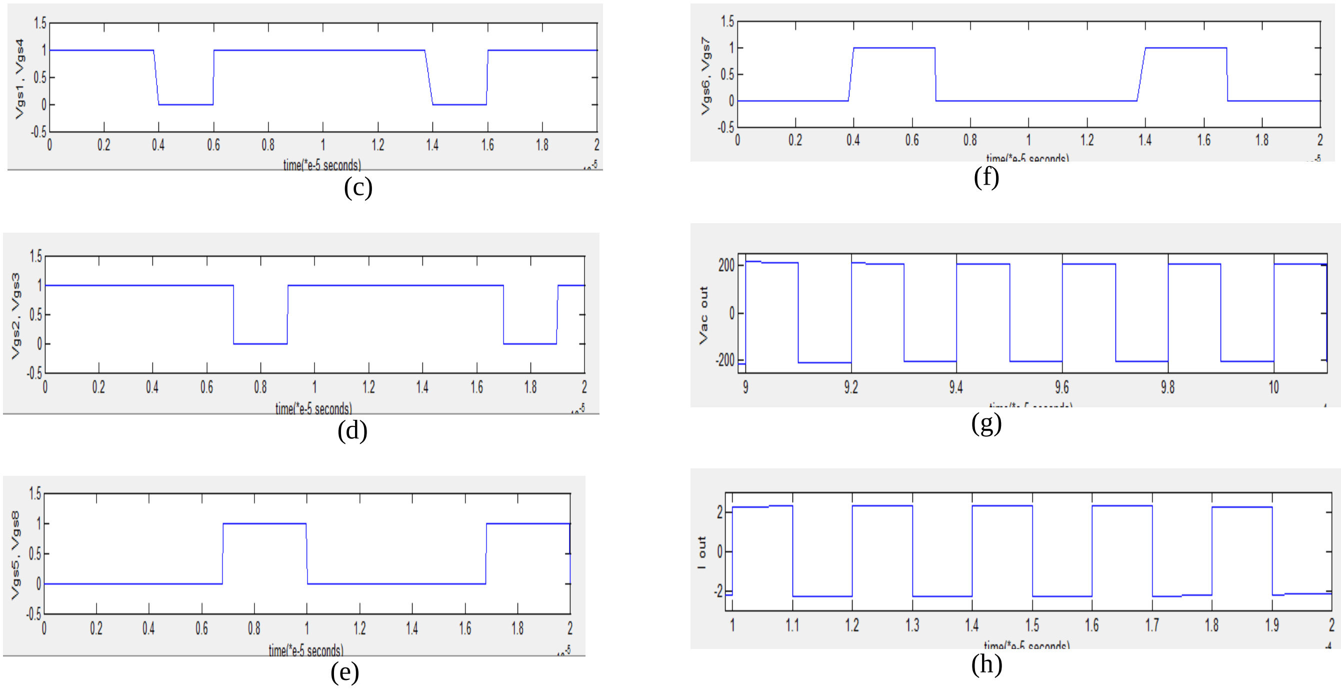


Fig 12. Simulation Results DC/DC converter (a) Primary voltage; (b) Output voltage;Gate switching:- (c) S1, S4 (d) S2, S3 (e) S5, S8 (f) S6, S7; Inverteroutput:- (g)output voltage (h) Output current

VI. CONCLUSION

A new dc/dc to converter is proposed in which use ZCStechnique in the primary and ZVStechnique in the secondary which ensure minimum switching loss. In the converter also use the possibility of ZCC and NVC. It therefore eliminatesthe need of an active-clamp or passive snubber.Usage oflow-voltage devices results in low conduction losses in primary devices, which is significant due to higher currents on the primary side. The proposed modulation method is simple and easy to implement. This dc/dc and dc/ac converter find applications in the modern electric vehicles as interface between battery and three phase motor. These merits make the converter promising for interfacing a lowvoltage dc bus with a high-voltage dc bus for higher current applications such as FCVs. Can be employed in front-end dc/dc power conversion for renewable (fuel cells/photovoltaic) inverters, uninterruptible power system, microgrid and energy storage.

REFERENCES

[1] Pan xuewei, Akshay e rathore "Novel bidirectional snubberless naturally commutated soft-switching current fed full-bridge isolated dc/dc converter for fuel cell vehicles" *IEEE transactions on industrial electronics,vol.61,no.5, may 2014.*
[2] K. Rajashekhara, "Power conversion and control strategies for fuel cell vehicles," in *Proc. 29th IEEE IECON*, 2003, pp. 2865–2870.
[3] A. Emadi, S. S. Williamson, and A. Khaligh, "Power electronics intensive solutions for advanced electric, hybrid electric, and fuel cell vehicular power systems," *IEEE Trans. Power Electron.*, vol. 21, no. 3, pp. 567– 577, May 2006.
[4] A. Emadi, K. Rajashekara, S. S. Williamson, and S. M. Lukic, "Topological overview of hybrid electric and fuel cell vehicular power system architectures and configurations," *IEEE Trans. Veh. Technol.*, vol. 54, no. 3, pp. 763–770, May 2005.
[5] A. Khaligh and Z. Li, "Battery, ultracapacitor, fuel cell, and hybrid energy storage systems for electric, hybrid electric, fuel cell, and plug-in hybrid electric vehicles: State of the art," *IEEE Trans. Veh. Technol.*, vol. 59, no. 6, pp. 2806–2814, Jul. 2010.
[6] F. Krismer, S. Round, and J. W. Kolar, "Performance optimization of a high current dual active bridge with a wide operating voltage range," in *37th IEEE PESC/IEEE Power Electron. Spec. Conf.*, Jun. 2006, pp. 1–7.
[7] H. Zhou and A. M. Khambadkone, "Hybrid modulation for dual active bridge bi-directional converter with extended power range for ultracapacitor application," *IEEE Trans. Ind. Appl.*, vol. 45, no. 4, pp. 1434–1442, Jul./Aug. 2009.

[8] L. Corradini, D. Seltzer, D. Bloomquist, R. Zane, D. Maksimovic, and B. Jacobson, "Minimum current operation of bidirectional dual-bridge series resonant DC/DC converters," *IEEE Trans. Power Electron.*, vol. 27, no. 7, pp. 3266–3276, Jul. 2012.
[9] X. Li and A. K. S. Bhat, "Analysis and design of high-frequency isolated dual-bridge series resonant DC/DC converter," *IEEE Trans. Power Electron.*, vol. 25, no. 4, pp. 850–862, Apr. 2010.
[10] W. Chen, P. Rong, and Z. Lu, "Snubberless bidirectional dc–dc converter with new CLLC resonant tank featuring minimized switching loss," *IEEE Trans. Ind. Electron.*, vol. 57, no. 9, pp. 3075–3086, Sep. 2010.