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A Bi-Directional DC-DC Converter with High Voltage Gain

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Abstract: In this paper, a non-isolated bidirectional DC- DC converter is presented. The proposed converter consists of two boost converters to enhance the voltage gain. Four power switches are employed in the proposed converter which their body diodes are also used. Two inductors and a capacitor are also employed as passive components. The input current is divided to the inductors which causes the efficiency to be high. The voltage gain of the proposed converter is higher than the Conventional Bidirectional buck/boost Converter (CBC) in step-up mode. The simple structure of the proposed converter causes its control to be easy. The steady state analysis of the proposed converter is discussed in this paper thoroughly. The closed loop simulations are done in both bucks as well as in boost mode of operation. Also some modifications are done in the circuit to act this as both buck and boost converter at the same time. Finally, the proposed converter prototype circuit is implemented to justify the validity of the analysis.

Keywords: High step-up converter, low voltage stress, non-isolated, reverses recovery, single switch, voltage doubler

I. INTRODUCTION

Nowadays, it is necessary to utilise clean and sustainable energy sources because of depletion of fossil reserves and environmental consequences of using them. With increasing demand for clean and sustainable energy sources recently, researchers pay more attention to suitable interface converters. Fuel cell (F.C.), wind energy and photovoltaic (PV) are renewable energies which have been widely applied to achieve environment friendly proposes. Dependence of the extracted power of the PV and wind energies on environmental specifications and low dynamic response off. Cs cause a storage element (battery) to be required in these systems. In order to charge and discharge the battery, a bidirectional converter is needed. Bidirectional converters transfer energy between two sources in both directions. Bidirectional DC-DC converters are widely used in various applications aerospace, uninterruptible power supplies (UPS), electric vehicles (EVs), photo voltaic hybrid power systems and many other appliances and industries. Depending on the application, isolated and non-isolated bidirectional converters are applied. Some of the isolated types of the bidirectional DC-DC converters are the fly back converters forward-fly back converters, half-bridge converters and full-bridge converters. Having large voltage gain in both step-up and step-down operation is one of the advantages of these converters. The fly back converters have simple structure and can be controlled easily. While the leakage-inductor energy cannot be recycled and the power switches of these converters suffer high-voltage stresses. In order to increase efficiency of these converters, the voltage clamp technique is applied to reduce voltage stresses on the switches. Non-isolated types of bidirectional converters comprise conventional boost/buck type ,multi-level type , three-level type, switched capacitor type, SEPIC/Zeta type and coupled inductor types. The multilevel type of converter has many switches. Also in the three-level type, voltage gain is low in both of step-up and step-down modes.

In this Thesis, a non-isolated bidirectional DC-DC converter is presented. The proposed converter has simple structure. Four power switches are employed in the proposed converter which their body diodes are also used. In each direction, two of the switches are used as power switches and the others are used as the synchronous rectifiers. The proposed converter has large voltage gain. Besides, the input current is divided to the inductors which cause the size of them to become smaller. The proposed converter consists of two conventional boost converters.

II.BI-DIRECTIONAL DC-DC CONVERTER WITH HIGH VOLTAGE GAIN

The proposed converter consists of two boost converters to enhance the voltage gain. Four power switches are employed in the proposed converter which their body diodes are also used. Two inductors and a capacitor are also employed as passive components. The input current is divided to the inductors which causes the efficiency to be high. The voltage gain of the proposed converter is higher than the Conventional Bidirectional buck/boost Converter (CBC) in step-up mode. Besides, the voltage gain in step-down mode is lower than CBC. Besides, the efficiency of the proposed converter more than CBC while the total stress on active switches are same. The simple structure of

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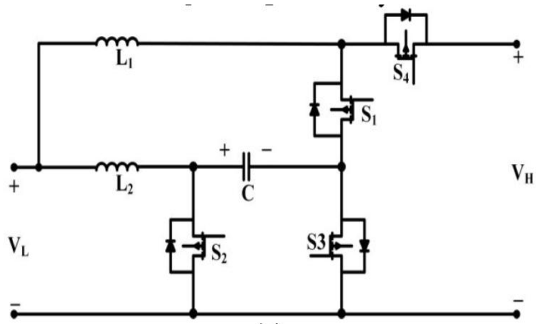
the proposed converter causes its control to be easy. The steady state analysis of the proposed converter is discussed in this paper thoroughly. The stress on converters' devices and CBC are compared in this paper.



(a)

Fig 2.1: Proposed bidirectional DC–DC converter

Fig.2.1 shows the system configuration of the proposed converter, which has a capacitor, two inductors and four switch-diodes. Two of the switches work as power switches and the remainders are applied for the synchronous rectifiers. The steady-state analysis of the proposed converter in step-up and step-down modes is discussed as follows. In order to analyze the steady-state characteristics of the proposed converter, the ON-state resistance R_{DS}(ON) of the switches and the equivalent series resistances of the inductors and capacitors are ignored and the voltages of the capacitors are constant.

III.OPERATIONAL PRINCIPLE

The proposed converter works both in step-up mode and step-down mode. Both the modes are explained in the following section.

A. Step-down mode

The proposed converter in step-down mode is shown in Fig.3.1. In this operation mode, S_3 and S_4 work as power switches and switches S_1 and S_2 are the synchronous rectifiers. Characteristic waveforms of the proposed converter in continuous conduction mode (CCM) are depicted in Fig.3.and the current flow path in one switching period is illustrated in Fig. 3. The steady-state analyses are described as follows.

Mode 1: During this time interval [t_0, t_1], S_3 and S_4 are turned on and S_1 and S_2 are turned off. The current-flow paths of the proposed converter are shown in Fig. 3.2(a). As seen in this figure, the energy of the DC source H_v is transferred to inductors L_1. Capacitor C is discharged to inductor L_2 and capacitor C_L. The following equations can be written in this mode:

$$V_{L1} = V_H - V_L \quad (1)$$

$$V_{L2} = V_C - V_L \quad (2)$$

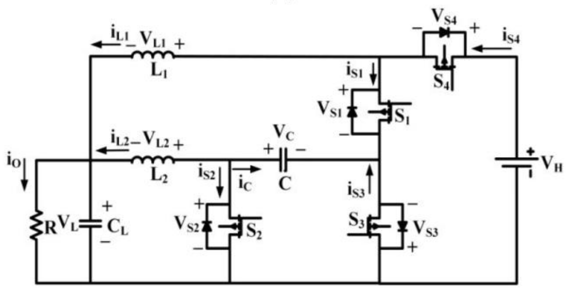


Fig.3.1: Equivalent circuit in the step-down mode

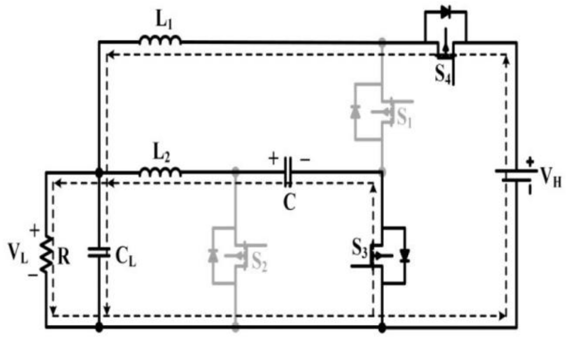


Fig.3.2 (a): Current-flow path of the proposed converter in the step-down mode. Mode 1

Mode 2: During this time interval [t1, t2], S1 and S2 are turned on and S3 and S4 are turned off. The current-flow paths of the suggested converter are shown in Fig. 3(b). Inductor L1 is demagnetized in this mode to capacitors C and CL. Inductor L2 is discharged to capacitor CL and provides energy to the load. Therefore, the voltages of inductors L1 and L2 can be written as:

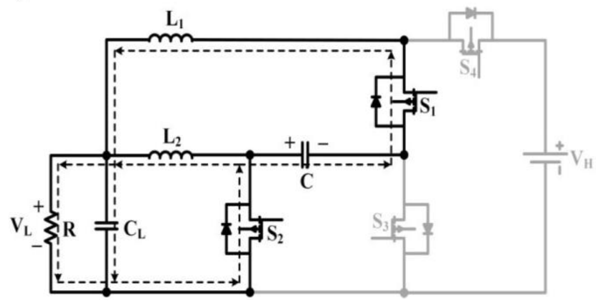


Fig.3.2(b): Current-flow path of the proposed converter in the step-down mode. Mode 2.

$$V_{L1} = -V_L - V_C \quad (3)$$

$$V_{L2} = -V_L \quad (4)$$

B. Step-Up mode

The proposed converter in step-up mode is shown in Fig.7. In this operation mode, S1 and S2 work as power switches and S3 and S4 are the synchronous rectifiers. The characteristic waveforms of the proposed converter in continuous conduction mode (CCM) are depicted in Fig.

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8.Fig. 9 illustrates the current flow paths in one switching period. The steady-state analyses are described as follows.

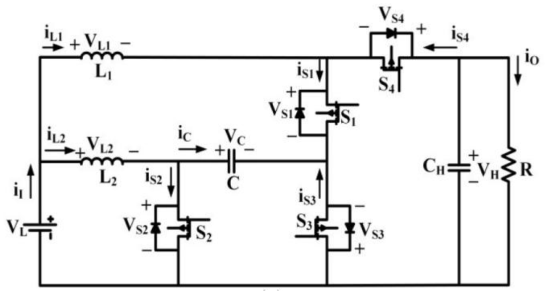

Fig.3.3. Equivalent circuit in the step-up mode

Mode 1: During the interval [t0, t1], S1 and S2 are turned on and S3 and S4 are turned off. As shown in Fig. 3.4(a), in this interval the energy of the DC source VL is transferred to inductor L2. Inductor L1 is magnetized by the DC source VL and the energy stored in capacitor C. Capacitor CH is also discharged to the load. The following equations can be obtained in this mode

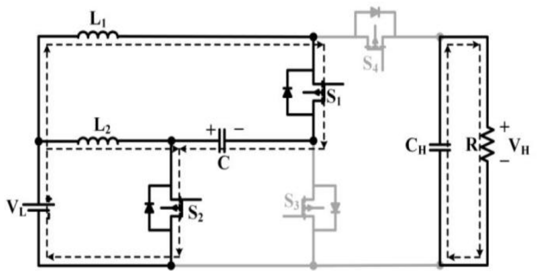

Fig.3.4(a) Current-flow path of the proposed converter in the step-up Mode 1.

$$V_{L1} = V_L + V_C \quad (5)$$
$$V_{L2} = V_L \quad (6)$$

Mode 2: During the interval [t0, t1], S1 and S2 are turned off and S3 and S4 are turned on. As shown in Fig. 9, capacitor C is charged by the input source VL and the energy stored in inductor L2. Capacitor CH is also charged by the input source VL and the energy stored in inductor L1.

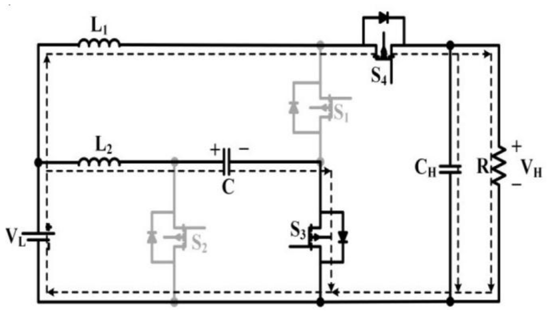

Fig.3.4(b) Current-flow path of the proposed converter in the step-up Mode 2.

Therefore, the voltages across the inductors can be written as:

$$V_{L1} = V_L - V_H \quad (7)$$
$$V_{L2} = V_L - V_C \quad (8)$$

IV. SIMULATION ANALYSIS AND RESULT

The closed loop simulation is done by two different methods for the generation of gate pulse is used. In the first method, feedback is fed from input side and the equations for the duty cycle is used to generate the gate pulse whereas in the second method a PI controller is used to control the switch.

A. Step-up converter mode

The simulation diagram of the converter in step up mode with feedback control is shown in fig 4.1 and fig 4.2 shows the feedback control. The fig 4.3 shows the simulation diagram of the converter with PI controller and fig 4.4 the controller as sub system corresponding simulation results are shown by fig 4.5, fig 4.6 and fig 4.7. The simulation analysis of the proposed converter in step-up mode is carried out on the basis of the following assumptions:

1) Input voltage (V_{in}) = 25V
2) Output voltage (V_o)= 250V
3) Switching frequency(f_s) = 30KHz
4) Duty ratio(D) =67%

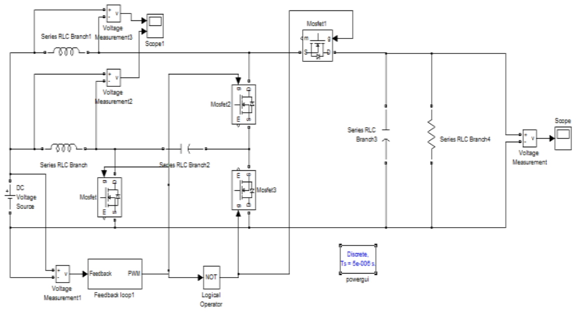

Fig.4.1.closed loop simulation diagram for step-up converter mode feedback from input

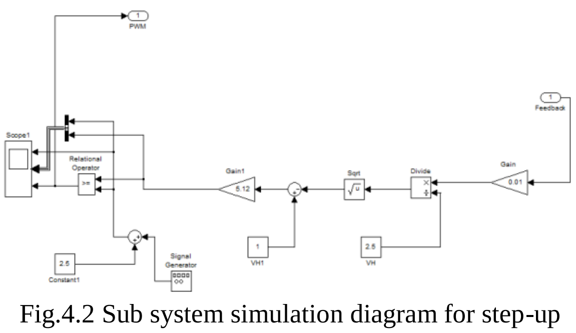

Fig.4.2 Sub system simulation diagram for step-up converter mode feedback from input

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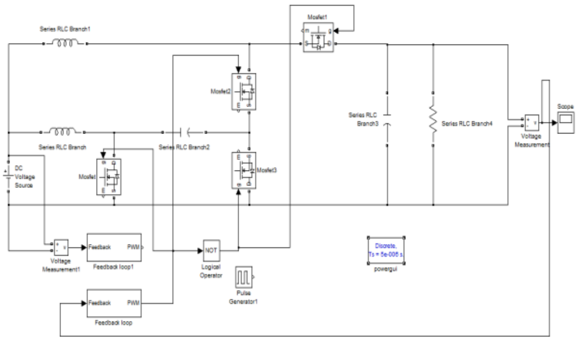

Fig.4.3.Closed loop simulation diagram for step-up converter mode feedback from output

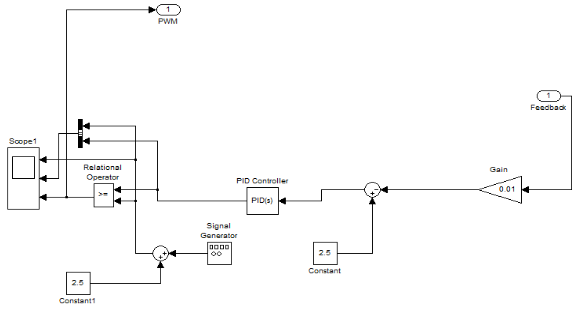

Fig.4.4.Sub system simulation diagram for step-up converter mode feedback from output

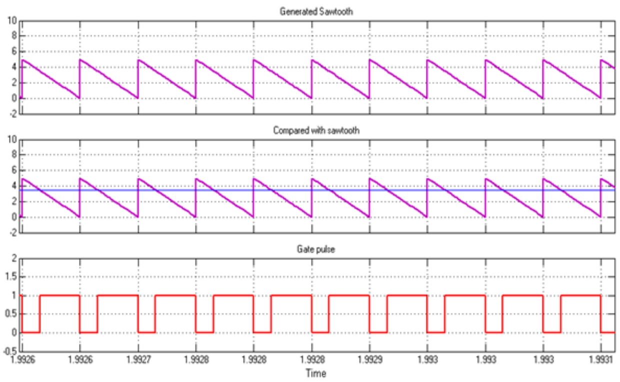

Fig.4.5 Generation of gate pulse in closed loop simulation

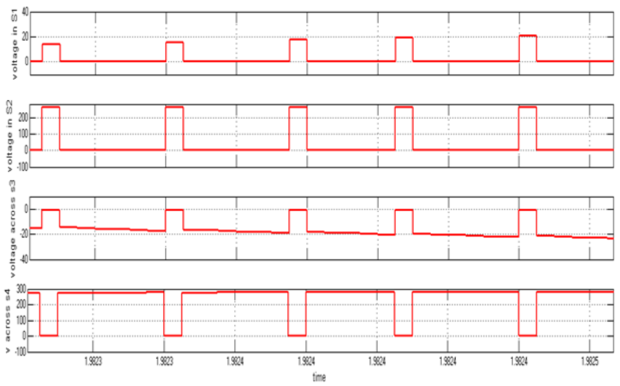

Fig.4.6.Voltage stress across four switches in step-up converter mode

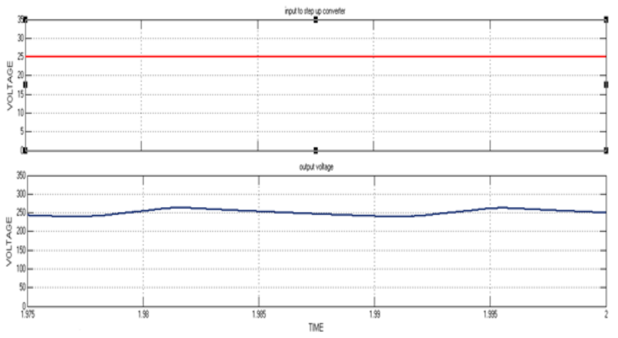

Fig.4.7.Simulation Results for step-up converter mode

B. Step-down converter mode

The simulation diagram of the converter in step down mode with feedback control is shown in fig 4.8 and fig 4.9 shows the feedback control and the corresponding simulation results are shown by fig 4.10, fig and fig 4 The simulation analysis of the proposed converter in step-up mode is carried out on the basis of the following assumptions:

1) Input voltage (V_{in}) = 250V
2) Output voltage (V_o)= 60V
3) Switching frequency(f_s) = 30KHz
4) Duty ratio(D) =67%

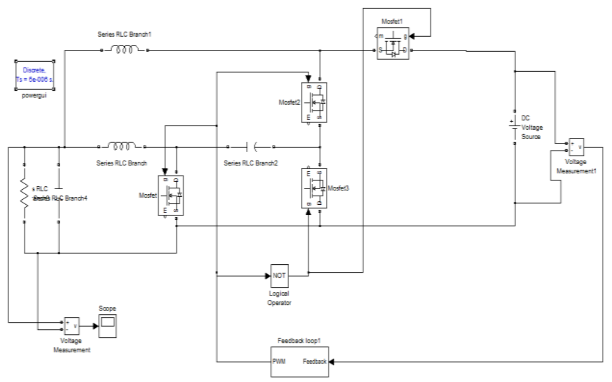

Fig.4.8. Closed loop simulation diagram for step-down converter mode using feedback control

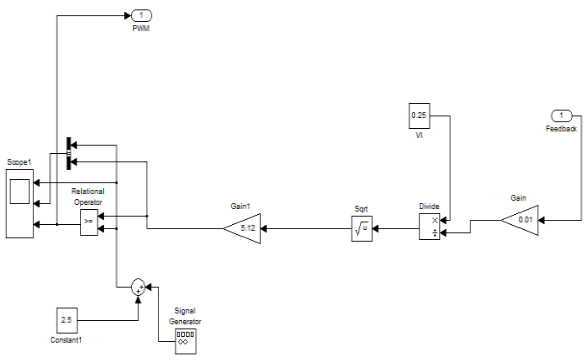

Fig.4.9.Sub system simulation diagram for step-down converter mode

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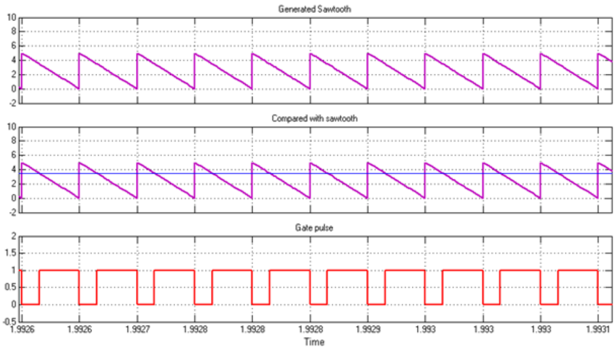

Fig.4.10 Generation of gate pulse in closed loop simulation

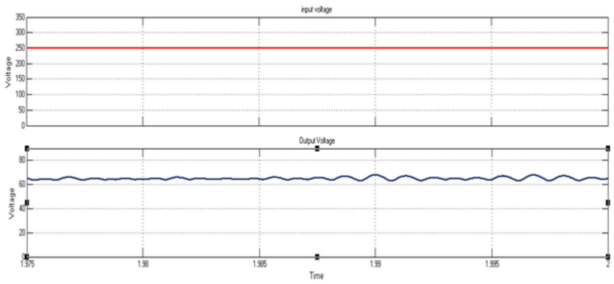

Fig.4.11.Simulation Results for step-down converter mode

The simulation is done for both the step-up as well as step-down modes of the proposed converteris shown in this section.

V.CONCLUSION

In this paper, a non-isolated bidirectional dc-dc converter with large voltage gain is analyzed. The proposed converter consists of four switches, two inductors and a capacitor. The voltage gain of the proposed converter in both step-down and step-up modes is more proper than the conventional bidirectional buck/boost converter. Besides, the input current is divided to the inductors. The steady-state analysis of the proposed converter is discussed thoroughly in this paper. In order to prove the feasibility of the presented converter, the proposed converter is simulated using MATLAB Simulink with the high and low side voltages 25 and 2.5, respectively. The effect of synchronous rectification is also verified.

REFERENCES

[1] Kwan-Hwa Lui, Fred C .Y Lee, "Zero-Voltage]Switching Technique in DC/DC Converters," IEEE tran. on power electronics,vol.5,no.3.july 1990.

[2] J inrong. Qian , Issa. Batarseh , M.Ehsani , "Analysis and Design of a Clamp-mode Isolated ZeroVoltage Switching Boost Converter," IEEE 1995.

[3] Praveen K.Jain, Wen Kang, Harry Soin and Youhao Xi, " Analysis and Design Considerations of a Load and Line Independent Zero Voltage Switching Full Bridge DC/DC Converter Topology," IEEE transactions on power electronics,vol.17.no.5 , Sep 2002.

[4] Luciano Schuch,Cassiano Rech, Helio Leaes Hey, Hilton Abilio Grundling, Humberto Pinheiro and Jose Renes Pinheiro, "Analysis and Design of a New High Efficiency Bidirectional Integrated ZVT PWM Converter for DC-Bus and Battery Bank Interface," IEEE Transactions on industry applications, vol.42,September/October 2006.

[5] Zhiling Liao and Xinbo Ruan, " A Novel Power Management Control Strategy for Stand-Alone Photovoltaic Power System," IEEE 2009.

[6] Tanmoy Bhattacharya, V.Shriganesh Giri, K.Mathew and L.Umanand, "Multiphase Bidirectional Fltback Converter Topology for Hybrid Electric Vehicles," IEEE Transactions on Industrial Electornics, vol.56,no.1,January 2009.

[7] F.Zhang and Y.Yan, " Novel Forward-Flyback Hybrid Bidirectional DC-DC Converter," IEEE Trans.Ind.Electron.,vol.56,no.5,pp.1578-1584,May 2009. [8] G.Ma, W.Qu, G.Yu, Y.Liu, N.Liang, and W.Li, "A Zero Voltage Switching Bidirectional DC-DC Converter with State Analysis and Soft Switching-Oriented Design Consideration,"IEEETras.Ind.Electron.,vol.56,no.6,pp.2174-2184,June 2009.

[9] X.Zhu, X.Li, G.Shen, and D.Xu, " Design of the Dynamic Power Compensation for PEMFC Disributed Power System," IEEE Trans.Ind.Electro,., vol.57,no.6,pp.1935-1944,June 2010.

[10] Y.P.Hsieh, J.F.Chen, T.J.Liang, L.S.Yang, " Analysis ad Implementation of a Novel Single-Switch High Step-up DC-DC Converter," IET Power Electron.,2011,vol.5,Iss.1,pp.11-21 11 doi: 10.1049/ietpel.2010.0279.

[11] A.Mirzaei, A.Jusoh, Z.Salam, E.Adib, H.Farzanehfard, " A Novel Soft Switching Bidirectional Coupled Inductor Buck-Boost Converter for Battery Discharging-Charging" , IEEE 2011.

[12] W.C.Liao, T.J.Liang, H.H.Liang, H.K.Liao, L.S.Yang, K.C.Juang, J.F.Chen " Study and Implementation of a Novel Bidirectional DC-DC Connverter with High Conversion Ratio" ,IEEE 2012.