Bidirectional Double Buck Boost Dc- Dc Converter

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Abstract— For renewable energy resources a new double buck boost coupled inductor based bidirectional converter is presented. With simple circuit high conversion ratio achieved. In order to achive a high step up conversion ratio by controlling one power switch, during discharging mode, its acts as a double boost converter. Similarly in order to achive a high step down conversion ratio by controlling two powers switches simultaneously during charging mode, its acts as a double buck converter. This two happen in high ratio as double buck boost is enabled. The advantage of this converter is energy stored in coupled inductor is recycled in order reduce leakage inductance; reduce switching loss, high voltage stress, hence we can achieve high efficiency. MATLAB is used to simulate the circuit and hardware prototype will do in open loop.

Key words: Bidirectional Converter, Coupled Inductor, High Conversion Ratio

I. INTRODUCTION

The bidirectional dc-dc converter has wide range of applications in battery charging, UPS, and hybrid vehicles. UPS is used for computers, telecommunication equipments, and electronic instruments. It is able to transfer or balanced energy between load and battery. When availability of renewable energy, energy is transferring from sources to the load and also transfers part of energy to the battery. During utility failure or renewable energy is insuffecient condition, the battery is transferred its stored energy continuously without interrupt to the load. The battery is used as a storage device or back up whenever utility failures. Fig.1.1.shows the block diagram Renewable energy hybrid system

The conventional buck-boost dc-dc converter is not able to provide high step up/down voltage gain ratio due to the presence of parasitic elements. But it has advantage like simple configuration. The other converters like forward fly back converters/ fly back converter, half bridge, full bridge converter, multilevel, switched capacitor type etc are have some disadvantages, like we have to adjust the turn ratio of the transformer and proper duty cycle in order to get high voltage gain ratio. Conventional buck-boost dc-dc converters are used only in low power applications. Leakage inductance, high current stress and conduction loss, high voltage spike on the power switch due to stored energy in inductor. Control circuit is also complicated.

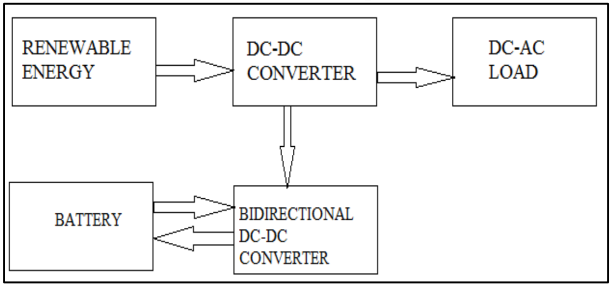

Fig.1.1.Renewable energy hybrid system

In order to overcome these problems, the proposed bidirectional double buck boost dc-dc converter is used to achive high voltage gain ratio. The coupled inductor technique which is used to reduces the leakage inductance current stress and conduction losses by recycled leakage inductance energy of the coupled inductor. It is also improves the efficiency by providing low R_{DS} –ON switch.

II. OPERATING PRINCIPLES OF THE PROPOSED CONVERTER

The proposed converter is able to transfer energy between two different dc sources. Such has low voltage side voltage 24V to the high voltage side 200V and the output power of 200W. It has two different modes such as discharging and charging mode is explain by its equivalent circuit diagram. Fig.2.1shows the proposed converter circuit with leakage inductances.

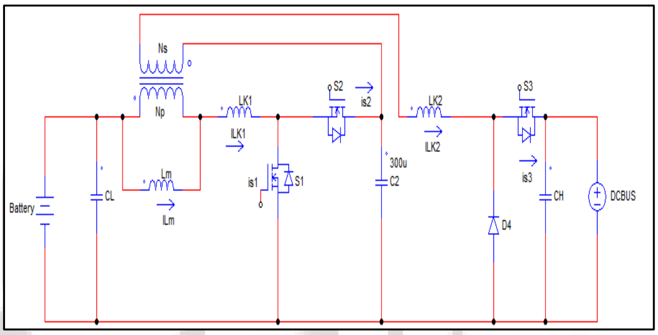

Fig. 2.1:Proposed converter circuit with leakage inductances

A. Discharging mode

In discharging mode converter acts as a two stage double boost converter by controlling the power switch S_1. The switch S_1 is the main power switch. The switches S_2 and S_3 are not conduct during the entire period. The explanations of different modes are described as follows.

Mode 1: During this mode 1, switch S_1 and diode D_{S3} are starts conducting. It is shows in below Fig.2.2 by its equivalent circuit. The Leakage inductor L_{K2} stored some energy that will transfer to C_H via i_{D3}, hence stored energy is gradually reduce in C_2, L_{K2}, I_{S3}.The battery transfer its energy into leakage inductor L_{K1}, hence current and its energy in the leakage inductor is slowly increases. The mode will be end when current I_{s3} comes to zero and diode D_{S3} is stopps conducting.

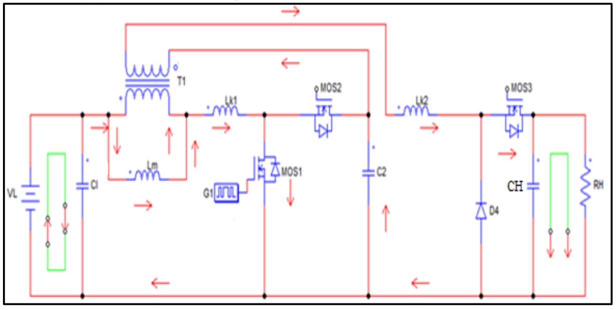

Fig.2.2 Equivalent circuit mode 1

Mode 2: During this mode switch S_1 and diode D_4 are starts conducting. It is show in below Fig.2.3.by its equivalent circuit.Baterry is continuously charging the magnetizing inductor Lm and the leakage inductor L_{K1} during this mode. Hence current flowing through the magnetizing-inductor current iLm and the leakage-inductor current iL_{k1} are linearly increased.C_2 get energy from V_L through N_S and D_4.the voltage appears across C_2 is equal to nV_L. This mode will end when s1 is stops conducting.

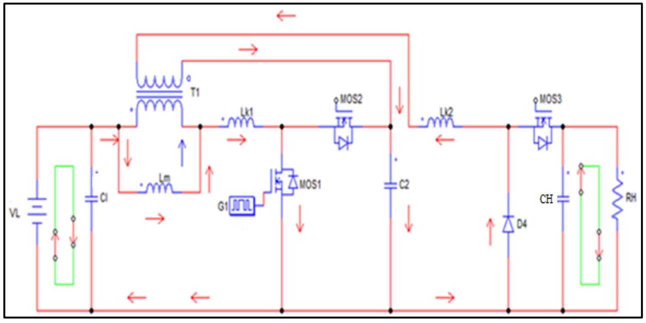

Fig .2.3.Equivalent circuit mode 2

Mode 3: During mode 3, $S1$ and D_{S3} are stops conducting and D_{S2} starting conducting. It is shown in below Fig.2.4.by its equivalent circuit diagram. The L_{K1} and L_{K2} transfer its energy into C_2 through D_{S2} and D_4, respectively. The mode will be end when current I_{LK2} flowing through I_{d4} is equal to zero and D_4 stops conducting.

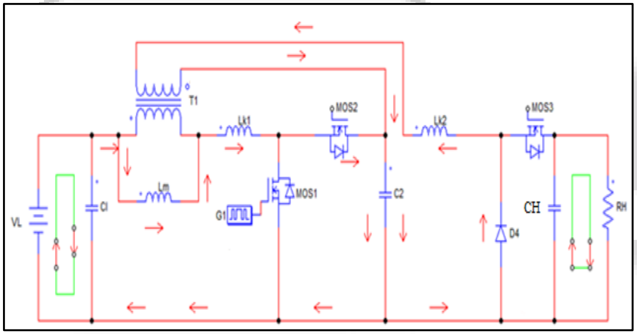

Fig. 2.4.Equivalent circuit mode 3

Mode 4: During mode 4, when S1 is stops conducting, and D_{S2} and D_{S3} are starts conducting. It is show in below Fig.2.5.by its equivalent circuit diagram. The capacitor C_2 is get energy by V_L,L_M and L_{K1} through D_{S2}.the Lm transfer its energy to load capacitor C_H and load resistance R_H through L_{K2}.. The mode will be end when voltage at, $C_2 = n$Vin.

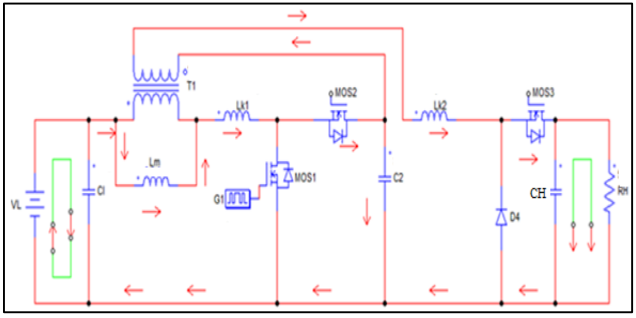

Fig. 2.5.Equivalent circuit mode 4

Mode 5: During mode 5, $S1$ is stops conducting, and D_{S2} and D_{S3} are starts conducting. It is shown in below Fig.2.6.by its equivalent circuit diagram. The energy transferring into C_H and R_H by Lm through L_{K1}, L_{K2} and also D_{S3}.this mode end when iL_{k1} is equal to zero.

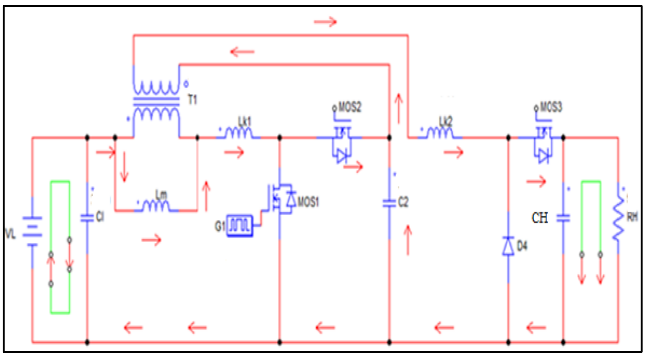

Fig. 2.6.Equivalent circuit mode 5

Mode 6: During mode 6, S_1 and D_{S2} are stopping conducting, and D_{S3} is starts conducting. It is show in below Fig.7.by its equivalent circuit diagram. The energy stored in Lm transfer into C_H and R_H through L_{K2} and D_{S3}. The energy stored in C_2 is also transferred to C_H and R_H.the mode will be end when S1 starts conducting.

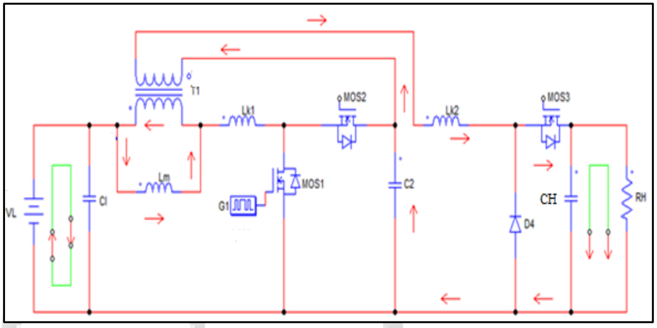

Fig. 2.7.Equivalent circuit mode 6

The voltage gain of the discharging mode is given as

$$VH/VL = n/1 - D. \qquad (2.1)$$

B. Charging mode:

In charging mode power switches s1 and s2 is conduct simultaneously and s1 is switch off for all modes. The explanations of different modes are described as follows.

Mode 1: During mode 1, the diode D_{S1} is starts conducting. It is shows in below fig.2.8.by its equivalent circuit diagram. Load capacitor C_L and load resistance R_L is get energy from Lm.Hence current in Lm in slowly decreases. The L_{K2} transfer energy to capacitor to C_2 which is recycled through D_4.The mode will be end when current I_{D4} comes to zero. Thus,

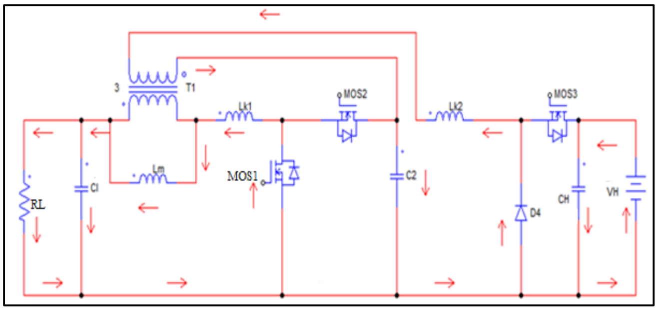

Fig. 2.8.Equivalent circuit mode 1

Mode 2 : During mode 2,the switches S_2 and S_3 are starts conducting.it is shows in below fig.2.9.by its equivalent circuit.The V_H transfer its energy to C_2,C_L ,R_L and also transfer energy to Lm, Lm start charging.the mode will be end when capacitor C_2 transfer its energy to R_L.

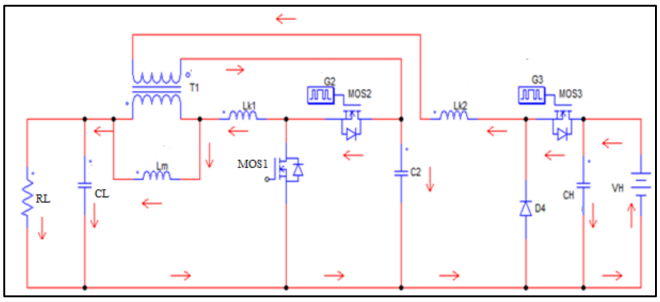

Fig.2.9.Equivalent circuit mode 2

Mode 3: During mode 3, the switches S_2 and S_3 still conducting. It is shows in below fig.2.10.by its equivalent circuit diagram.V_H and C_2 transfer its energy to Lm, C_L and R_L. Lm gets energized slowly by transferred energy. The mode will be ends when S_2 and S_3 are switch off.

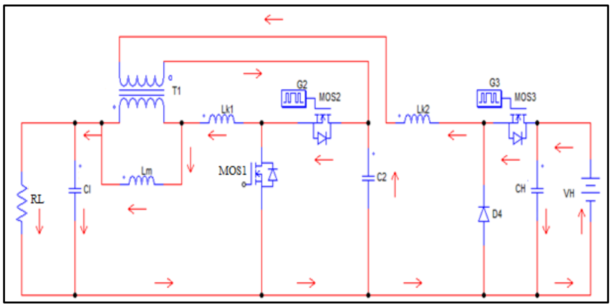

Fig.2.10.Equivalent circuit mode 3

Mode 4: During mode 4, switches S_2 and S_3 are switch off and D_{S1} is switch on .It is shows in below fig.2.11.by its equivalent circuit diagram. The energy stored in inductor L_{K1}, transfer its energy to C_L and similarly L_{K2} transfer energy to C_2.the mode will be end, when stored energy in L_{K2} completely transfer to zero. Thus,

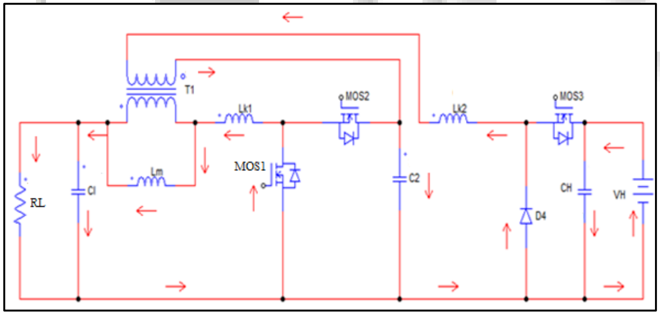

Fig.2.11. Equivalent circuit mode 4

Mode 5: During mode 5, the switches S_2 and S_3 are switch off and I_{Ds1} is still conducting. It is shows in below fig.2.12.by its equivalent circuit diagram. The Lm transfer its energy to both C_L and R_L.C_2 get energy via N_S and D_4.

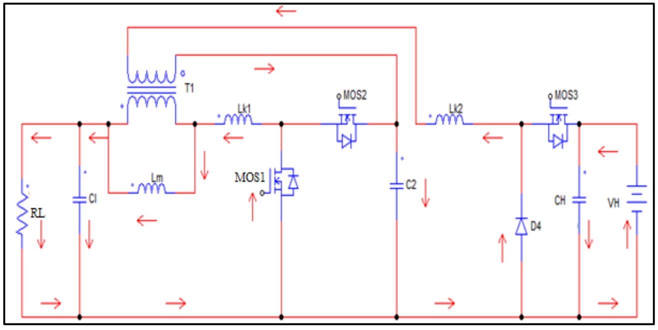

Fig.2.12. Equivalent circuit mode 5

The voltage gain of the charging mode is given as

$$V_L/V_H = D/\ 1 + n - nD. \qquad (2.2)$$

III. SIMULATION RESULTS

The operation of different modes in discharging and charging mode is learned by above its equivalent circuit model. We have get simulation results by Simulink model and converter parameters are give in below table 1.

Symbols	Names	Values
V_L	Input DC voltage	24V
V_H	Output DC voltage	200V
A	voltage gain	8.33
f_{sw}	Switching frequency	50k
L_m	Magnetizing inductance	37mh
N_P and N_S	Turns ratio	1:3
L	Inductor (L_{K1} & L_{K2})	0.33uH
C	Capacitor (C_2 & C_H)	300uF
C_L	Load capacitance	220uF
D	Discharging mode	67%
D	Charging mode	35.5%
P_{out}	Output power	200W

Table .1: Parameters for Simulation

IV. DISCHARGING MODE

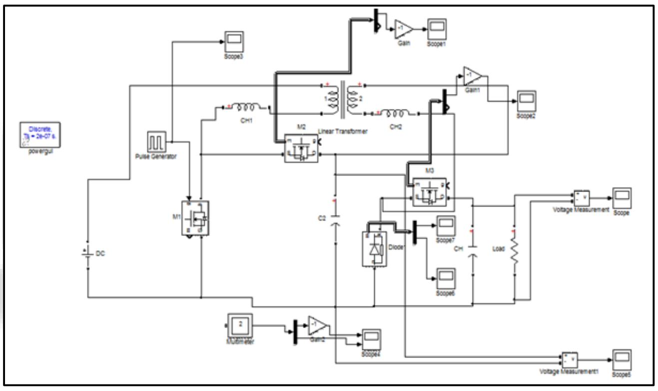

Fig. 3.1. Simulation circuit for discharging mode

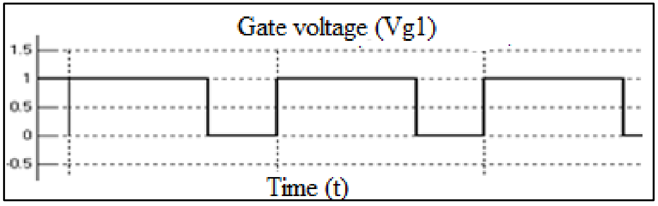

Fig. 3.2.Gate voltage V_{G1}

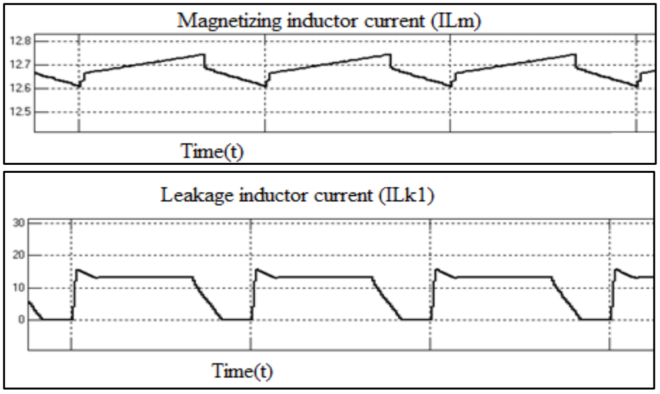

Fig. 3.3.Magnetizing current (I_{Lm}) and leakage current (I_{Lk1})

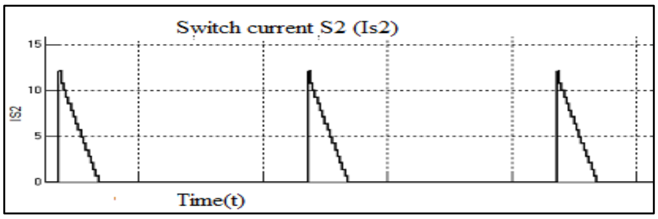

Fig. 3.4.Switch current S_2 (I_{S2})

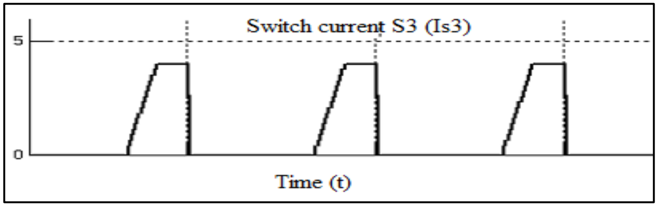

Fig. 3.5.Switch current S_3 (I_{S3})

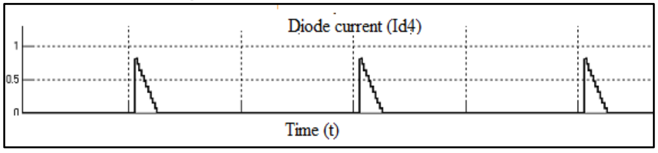

Fig. 3.6. Diode current (I_{D4})

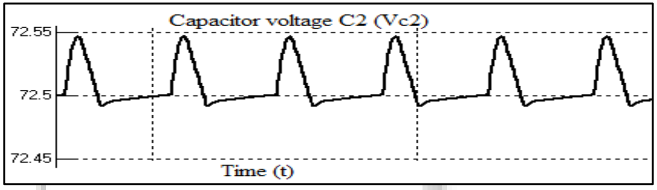

Fig . 3.7.Capacitor voltage C_2 (V_{C2})

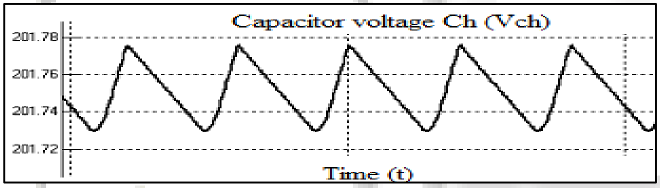

Fig. 3.8. Capacitor voltage C_H (V_{CH})

A. *Charging mode*

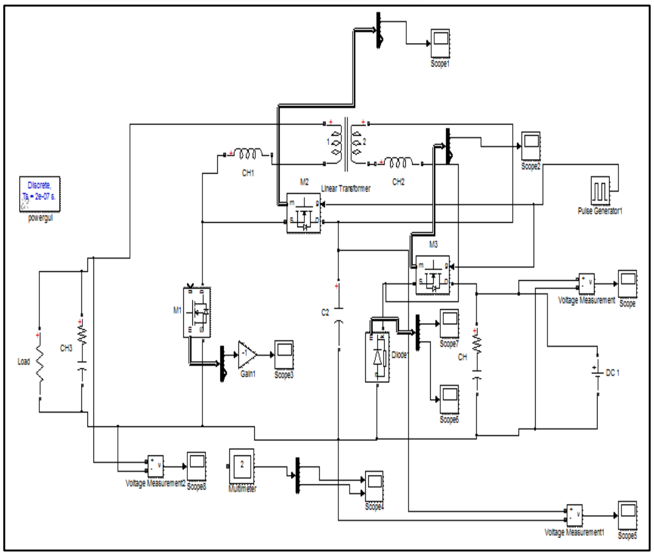

Fig. 3.9.Simulation circuit for charging mode

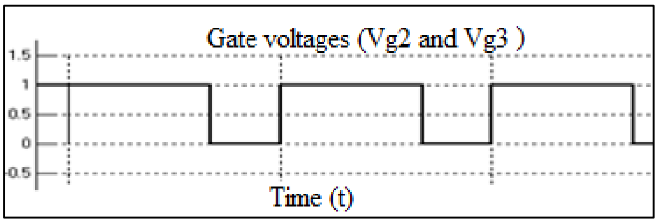

Fig. 3.10.Gate voltages V_{G2} and V_{G3}

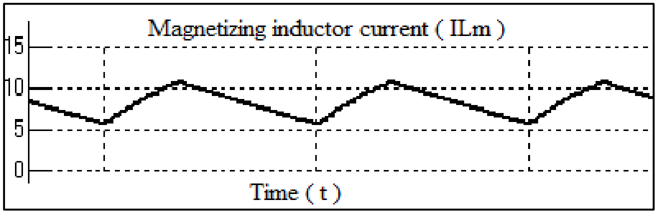

Fig. 3.11.Magnetizing inductor current (I_{Lm})

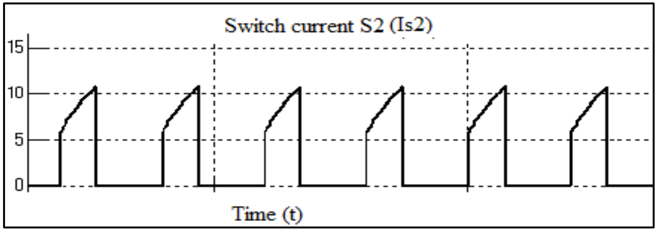

Fig. 3.12.Switch current (I_{S2})

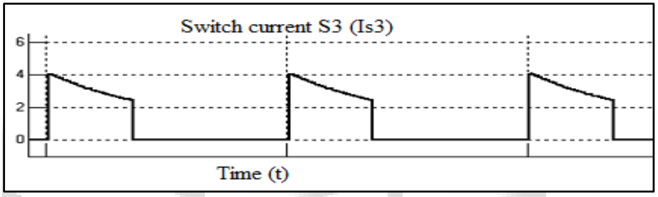

Fig. 3.13. Switch current (I_{S3})

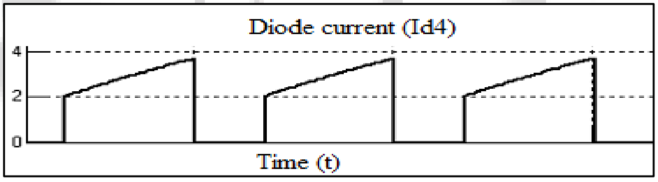

Fig. 3.14. Diode current (I_{D4})

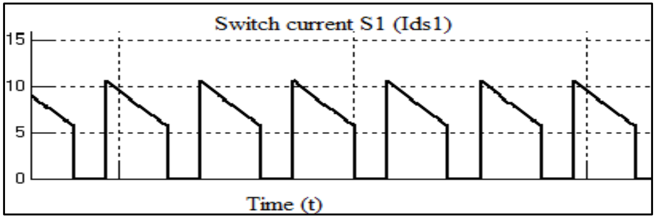

Fig. 3.15. Switch current (I_{Ds1})

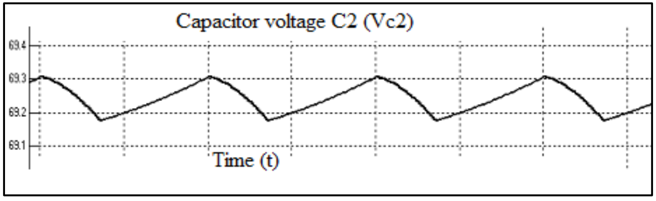

Fig. 3.16. Capacitor voltage (V_{C2})

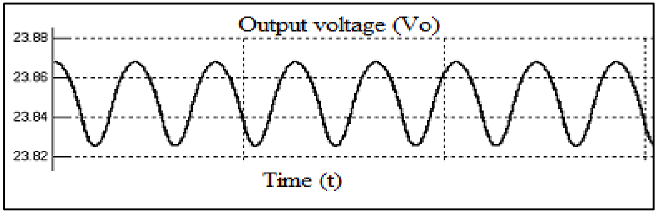

Fig. 3.17. Output voltage (V_O)

B. *Closed loop operation for discharging mode:*

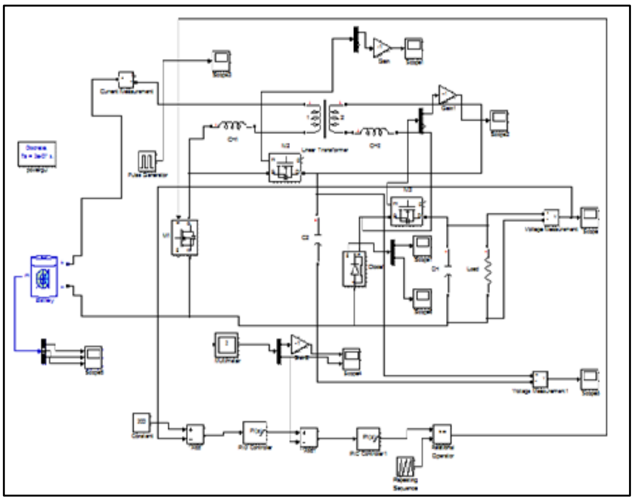

Fig. 3.18.Close loop simulation module for discharging mode

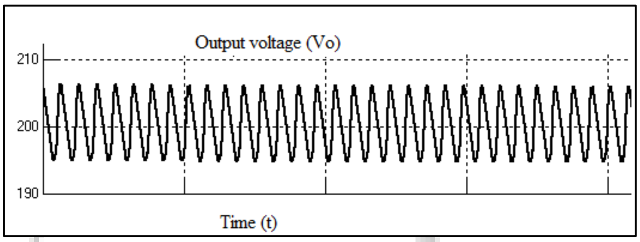

Fig.3.19. Output voltage in close loop

C. *Closed loop operation for charging mode:*

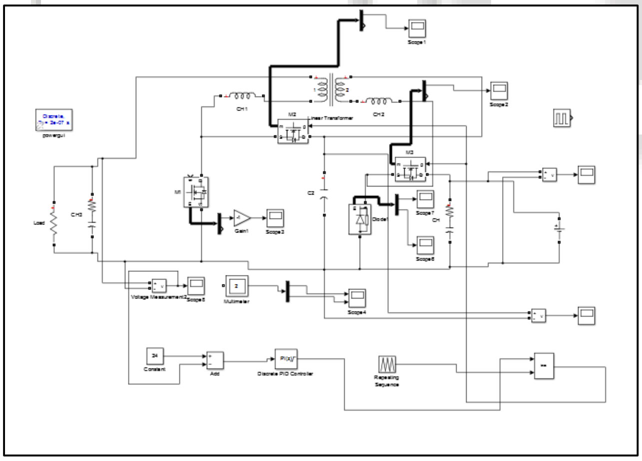

Fig. 3.20.Close loop simulation module for charging mode

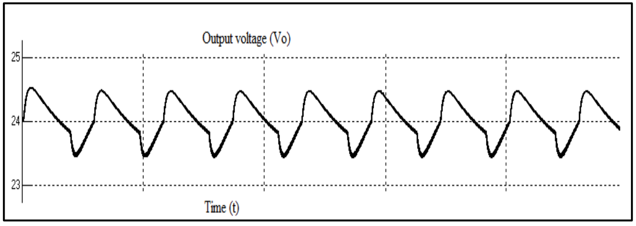

Fig. 3.21.output voltage for charging mode

V. CONCLUSION

This paper presents a bidirectional double buck boost dc -dc converter for renewable energy systems. The coupled inductor technique is used to achieve high step up/down conversion ratio during discharging and charging operation. The leakage inductance, high voltage spike in power switches, high current stress and conduction loss can be reduce by using couple inductor technique. This converter can be used for high voltage applications. High efficiency is achieved by recycled the coupled inductor energy.

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