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Performance Analysis of High Step-Up Dc-Dc Converter for PV System fed BLDC Motor drive

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Abstract:

In this paper, the conventional DC-DC converter is replaced with a High Step-up Converter for the solar power applications. The performance of converter-inverter technology to drive a brushless DC motor is analyzed. The high step-up dc-dc converters are used to produce high step-up gain. Theoretically the boost converter can provide the high voltage gain at large duty cycle. But in practice the voltage gain is reduced, due to losses in utilized components like rectifier diode, power switch, inductor and capacitor. Hence the converter using coupled inductor technique was introduced. However, the leakage inductor cause voltage transients on main switch and also reduce the conversion efficiency. To mitigate the voltage stress on the main switch due to voltage spike/transients, the coupled inductor with active clamp circuit based converters are introduced. They are different from other existing DC_DC step up converter and possess obivious advantages, mainly including fewer switches, clear conversion processes and a high voltage with simple ripples. The speed of the BLDC motor is controlled by varying the dc-link voltage source inverter (VSI). A low-frequency switching of the VSI is used for achieving the electronic commutation of BLDC motor for reduced switching losses. The voltage transformation is doubled. The simulations are done with MATLAB/SIMULINK and the results are exhibited.

Index Terms—PV panel, voltage source inverter, DC-DC converter, BLDC motor.

I. INTRODUCTION

Renewable energy plays a major role in distributed generation system. Thus, the energy sources causing problems like green house effect, global warming and fossils exhaustions are completely avoided. When considering the secure, robust and pollution free environment [1- 5]. Thus, the PV module becomes the better contribution for generating electricity among the renewable energy sources. In generally, the front stage conversion process will be high step up dc-dc converter. Non-isolated dc-dc converter will be used for smaller conversion ratio. These converters can be useful for low power applications [6].

In recent years, the boost converter is applicable to produce high conversion ratio. But in practical consideration, it is not possible to achieve a high conversion ratio without using a large duty cycle. Due to larger duty ratio and higher components rating, the series problems like reverse recovery, voltage stress and electromagnetic interference will occurs [7-8].In order to avoid the reverse recovery problem, the better solution to use a transformer or coupled inductor [9-10].

The transformer has a certain limitations like magnetizing and leakage inductances. So, the coupled inductor is simple and better to reduce the conduction loss and current ripple. The secondary side of the coupled inductor will be act as fly back converter, because the capacitor voltage is adjusted by varying the turn ratio. It also degrades the efficiency. In order to achieve the high voltage gain, the switched capacitor technique was introduced [11]. So, the capacitor can charge in parallel and discharge in series. To reduce the voltage stress on the power switch, the low voltage rating

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switch Rds (ON) will be selected. Due to this selection, the voltage spike across the switch is reduced significantly. By cascading the boost converter with fly back converter in series, it also improves the voltage gain. By using the concept of coupled inductor and switched capacitor technique the voltage gain is achieved and it also consists of low conduction loss, voltage stress and input current ripple [12].
Moreover, the coupled inductor is complex to handle by engineers. By using of power switch will produce the voltage transients and power loss. Due to this problem, non dissipative snubber circuit and active clamp circuit was proposed. But it has certain demerits like complexity, high cost for additional switch requirement [13]. Thus, the proposed converter introduced the switched capacitor coupled-inductor technique. In addition, the lossless passive clamp circuit is added to recycle the leakage inductor energy. So that, the power loss and voltage spike across the switch is reduced. Then, the efficiency also improved [14].

II. CONVENTIONAL TOPOLOGIES

The conventional topology proposed a clamp mode coupled inductor boost converter. In order to achieve a high voltage gain, the clamp mode coupled inductor boost converter is cascaded with the fly back converter. Thus, the power switch S1 with low resistance Rds (ON) is selected to reduce the voltage stress across the utilized components like diode, capacitor and switch. It also reduces the conduction loss. So, the overall efficiency also improved. To reduce the voltage spike across the switch S1, the capacitor C1 will be act as output capacitor and snubber capacitor.

(A) Circuit Configuration

The circuit configuration of the conventional topology is shown in Fig 1. it consists of dc input voltage Vin, power switch S1, coupled inductor, two diodes D1 and D2, and two capacitor C1 and C2. Thus, the equivalent circuit of coupled inductor will be replaced with an ideal transformer N1 and N2, leakage inductor Lk and magnetic inductor Lm as shown in Fig 2.

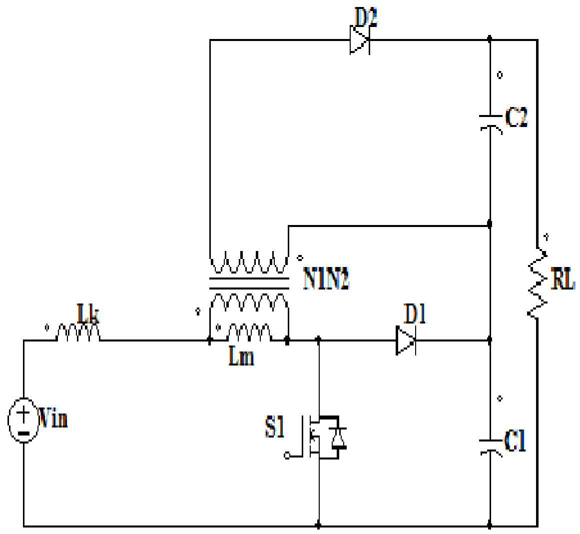

Fig1 Clamp mode coupled inductor boost converter.

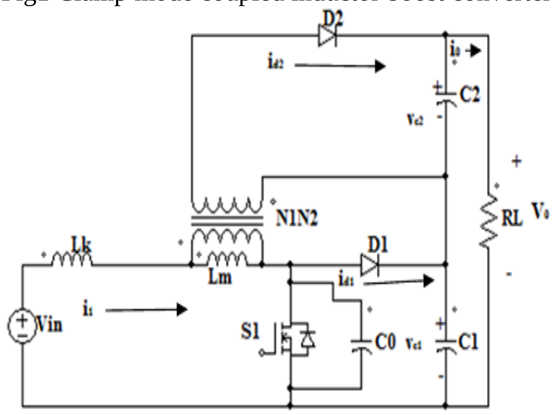

Fig 2 Equivalent circuit of the Clamp mode coupled inductor boost converter

(B) Operational Principle

The main operating principle of conventional converter considered only CCM of operation. Thus, the voltage across the output capacitor C1 and C2 will be large enough to supply the energy to the load RL. So, it made as constant.

(C) Continuous-Conduction Mode (CCM) Operation: The waveform of continuous conduction mode (CCM) of operation is shown in Fig.3

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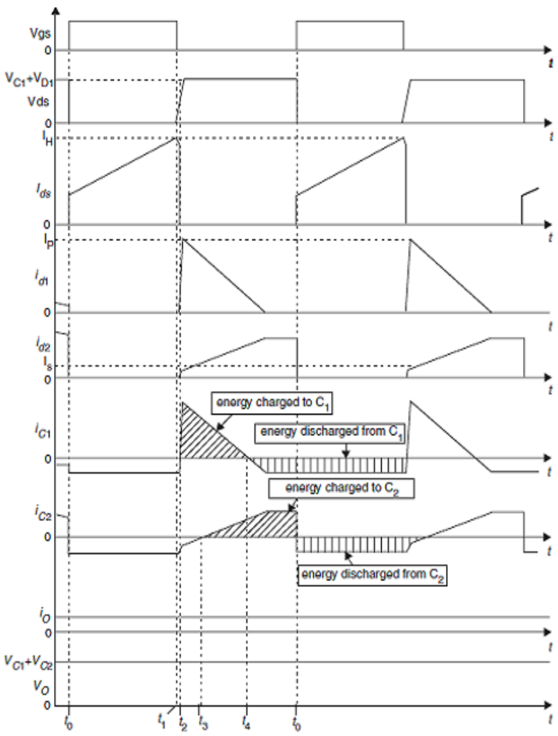
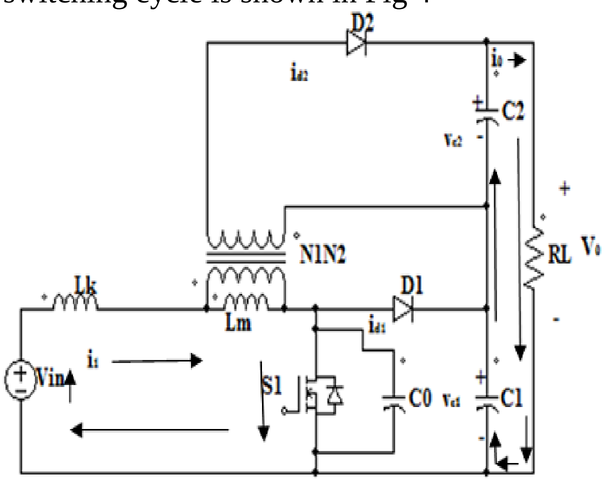


Fig 3 Typical waveform of the proposed converter at CCM operation.

The current flow path of CCM operation at one switching cycle is shown in Fig 4



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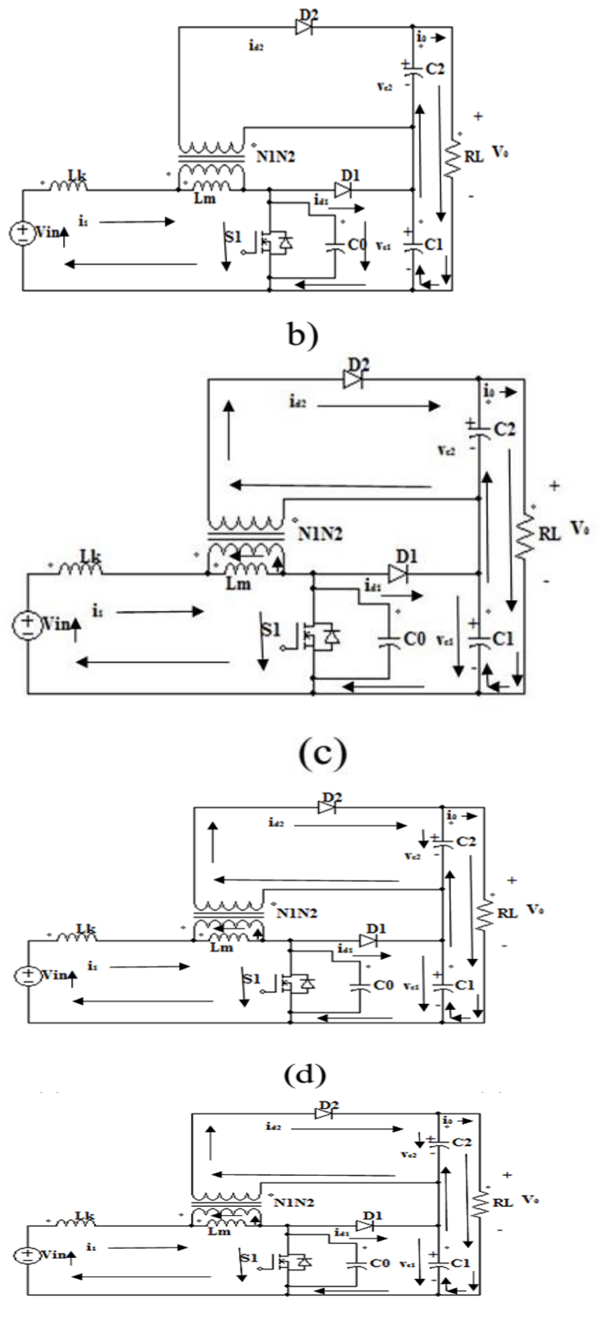

Fig 4 Current flow path of operating modes during one switching period at CCM a) mode-I, b) mode-II, c) mode-III, d) mode-IV, e) mode-V

Mode-I [t0-t1]: In mode-I operation, the switch S1 will be ON state as shown in Fig.4a. Thus, the dc input voltage Vin will be equal to the voltage across Lm. So, ilm increases. Then, diode D1 is reversed biased and the output capacitor C1 and C2 will discharge the energy to the load RL. When the time instance of t1, the ilm(peak) will be obtained.

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Mode-II [t1-t2]: In mode-II operation, the parasitic capacitor C0 of the power switch S1 will be charged by the magnetic inductor Lm as shown in Fig .4b. Until the time instances t=t2, the voltage across C0 will be increases.

Mode-III [t2-t3]: In mode-II operation, diode D1 and D2 starts conducts as shown in Fig.4(c). The magnetizing current will be flow through the output capacitor C1 by leakage inductor current. This, the id1 current starts decreases and id2 current starts increases which is act as complementary.

Mode-IV [t3-t4]: In mode-II operation, ic2 becomes positive as shown in Fig. 4(d). The energy is charged through C2 and supplies the load current. Simultaneously, the capacitor C1 is charged by id1 and it also supplies the load current.

Mode-V [t4-t0]: In mode-II operation, ic1 will be equal to zero as shown in Fig. 4(e). The energy is discharged to C1 and supplies the load current. Simultaneously, the capacitor C2 is charged by id2 and it also supplies the load current. This mode ends at t0band the switching cycle repeats.

III PROPOSED TOPOLOGY

In order to overcome the problem of conventional topology, we proposed a high step-up ratio and clamp mode converter to achieve a high step-up voltage gain and high efficiency. In this topology, the converter consists of two capacitors and two diodes which are added on the coupled inductor secondary side. So, the coupled inductor makes the capacitor to discharge in series and also to charge in parallel. Moreover, there is a problem of using the coupled inductor. Because the leakage inductor of the coupled inductor can produce high voltage transients on the power switch. In order to reduce the voltage spikes across the switch and also to recycle the leakage energy, the lossless passive clamp circuit is proposed.

(A) Circuit Configuration

The circuit configuration of high step-up dc-dc converter with passive clamping circuit is shown in Fig.5 . it consists of dc input voltage Vin, coupled inductor, power switch S, one clamp capacitor C1 and one clamp diode D1, one output diode D0 and one output capacitor C0. The passive clamping circuit consists of two capacitor C2 and C3, two diodes D2 and D3. The equivalent model of circuit configuration consists of leakage inductor Lk, magnetic inductor Lm and an ideal transformer instead of coupled inductor. The coupled inductor had a certain limitation like large input current ripple. The secondary side of the coupled inductor is act as a transformer in the forward converter and fly back converter. By varying the turn ratio, the capacitor voltage is adjusted and the high voltage gain is achieved without adding any winding stage of the coupled inductor.

In order to achieve the high voltage gain, the switched capacitor technique was proposed. In this topology, the high step-up voltage gain can be achieved without using a large duty cycle. From this switched capacitor technique, that the capacitor can charge in parallel and discharge in series. Based on this technique, the proposed converter introduced the combination of coupled inductor and switched capacitor technique. The proposed converter adds the capacitor C2 and C3 on the coupled – inductor secondary side. When the switch is turned ON, the capacitor C2 and C3 will charge in parallel. At the same time, when the switch is turned OFF, it will discharge in series.

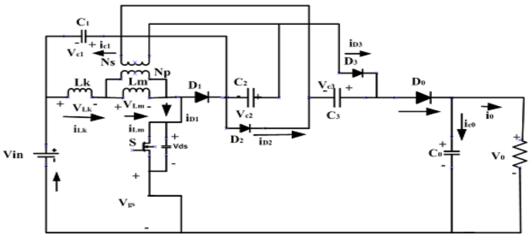

Fig.5. Circuit Configuration of the Proposed Converter System

The passive clamp circuit is used to recycle the leakage inductor energy to capacitor C1 and also the voltage spikes occurs in the power switch S can be clamped. So, the voltage stress is reduced when compared to the conventional topology. By selecting the low resistance

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Rds(ON) of the switch, the conduction loss is reduced significantly. From this concept, we can reduce the voltage stress, cost and conduction loss. By recycling the energy, the reverse recovery problem is reduced and also high efficiency is achieved. In addition, the high step-up voltage gain is achieved.

(B) Operational Principle

The operating principle of the proposed converter describes in different modes of switching period. When the power switch S is in ON state, the dc input voltage Vin will charge the magnetic inductor Lm and the secondary side of the coupled inductor will induces voltage like Vc1, Vc2 and Vc3. Thus, the induced voltages are connected in series to discharge a high voltage to the output. At the time of switch in OFF state, the stored energy of the magnetic inductor Lm will releases energy through the coupled-inductor secondary side. So, the capacitor C2 and C3 will be charged in parallel. Thus, the proposed topology will be operated in both continuous conduction mode (CCM) of operation and discontinuous conduction mode (CCM) of operation.

(C)Continuous-Conduction Mode (CCM) Operation:

From this table-I of CCM operation, we can describes the time interval, switch turn on and off period and also the devices should turn on and off sequences for the certain switching period. The waveform of continuous conduction mode (CCM) of operation is shown in Fig.6.

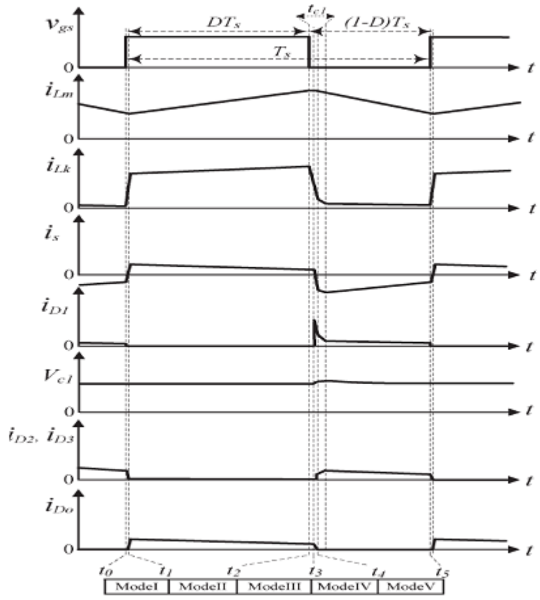
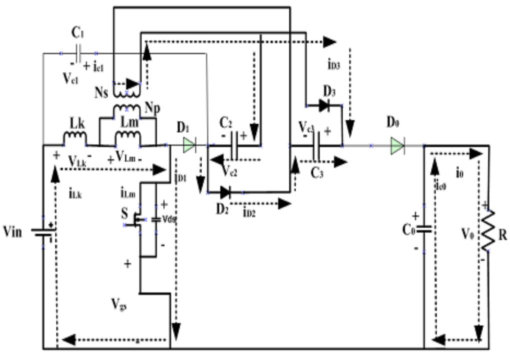


Fig.6. Typical waveform of the proposed converter at CCM operation

The current flow path of CCM operation at one switching cycle is shown in Fig. 7.

Table-I for CCM operation

Modes	Stage	Switch S	Devices ON	Devices OFF
I	t_0-t_1	ON	D_2 and D_3	D_1 and D_0
II	t_1-t_2	ON	D_0	D_1,D_2 and D_3
III	t_2-t_3	OFF	D_0	D_1,D_2 and D_3
IV	t_3-t_4	OFF	D_1 and D_0	D_2 and D_3
V	t_4-t_5	OFF	D_1,D_2 and D_3	D_0



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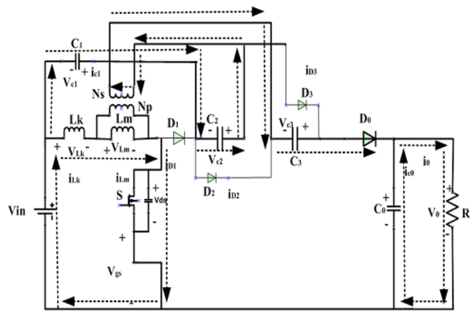

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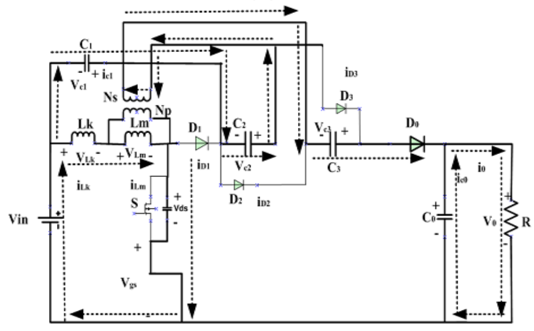

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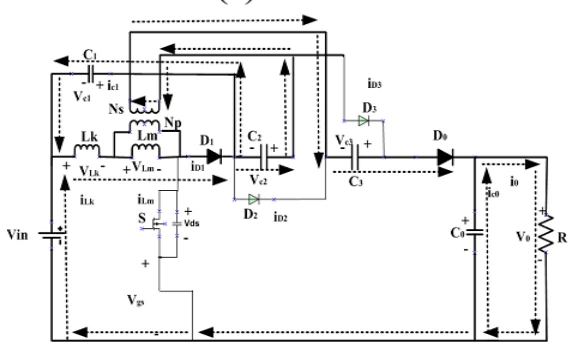

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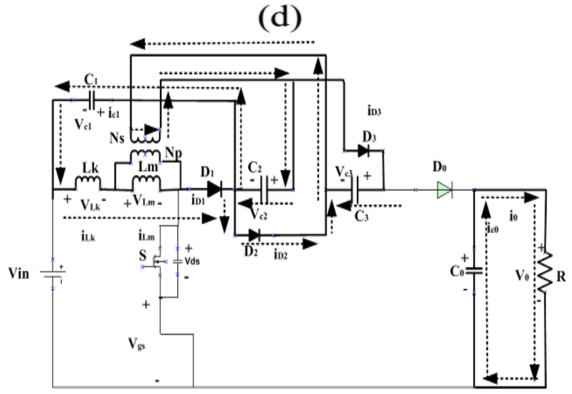

(e)

Fig.7. Current flow path of operating modes during one switching period at CCM a) mode-I, b) mode-II, c) mode-III, d) mode-IV, e) mode-V

Mode-I [t0-t1]: In mode-I operation, the dc source Vin charge the leakage inductor Lk. So, the coupled inductor side current is decreased linearly. At the same time, output capacitor C0 will release energy to the load R. when t=t1, id2 current becomes zero.

Mode-II [t1-t2]: In mode-II operation, the dc source Vin charge the magnetic inductor Lm. So the secondary side coupled inductor can induces some voltages like VC1, VC2 and VC3 which are connected in series. The induced voltage will be large enough to release the energy to the output capacitor C0 and load R.

Mode-III [t2-t3]: In mode-III operation, the parasitic capacitor Cds of the power switch will be charged by the energy stored in the leakage inductor and magnetic inductor. Thus, output capacitor C0 will gives energy to the load R.

Mode-IV [t3-t4]: In mode-IV operation, diode D1 conducts. The clamp capacitor C1 is charged by the leakage inductor and magnetic inductor. The leakage energy is recycled then the leakage current ilk is decreases quickly. The secondary side induced voltage will continuous until the secondary current is becoming zero.

Mode-V [t4-t5]: In mode-V operation, output diode current iD0 is zero. The charging of clamp capacitor C1 will continues and the energy stored in the leakage inductor Lk will release through the secondary side coupled inductor. Thus, the energy makes capacitor C2 and C3 to charge in parallel. When it charges capacitor C1, the leakage current ilk will decreases and it starts increasing the secondary side current is. This mode of operation will be end at t=t6 and the switching period will be starts to repeat.

(C) Discontinuous-Conduction Mode (CCM) Operation

The waveform of discontinuous conduction mode (DCM) of operation is shown in Fig.8. The current flow path of DCM operation at one switching cycle is shown in Fig.9.

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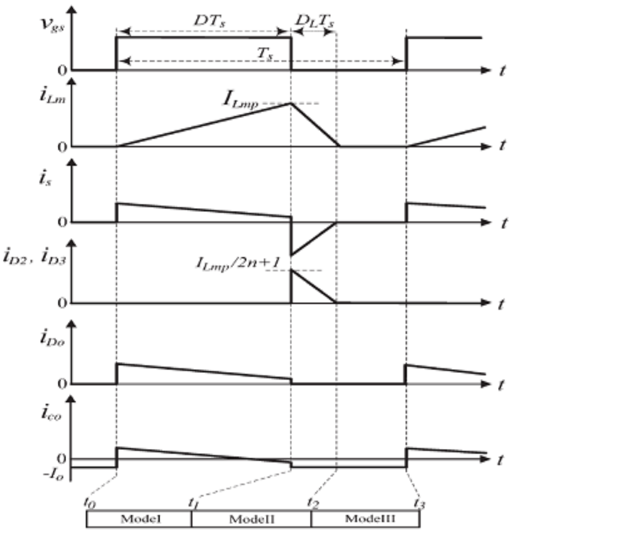
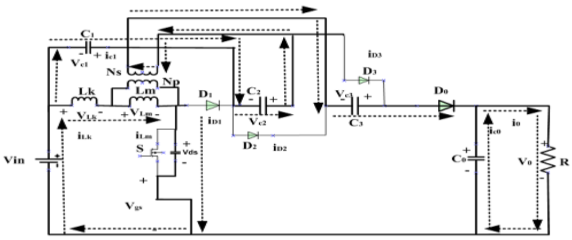


Fig.8. Typical waveform of the proposed converter at DCM operation

From this table-II of DCM operation, we can describes the devices to be on and off, time interval and switch turn on and turn off period for the certain switching period.

Table-II for DCM operation

Modes	Stage	Switch(S)	Devices ON	Devices OFF
I	t_0-t_1	ON	D_2 and D_3	D_1 and D_0
II	t_1-t_2	OFF	D_0	D_1,D_2 and D_3
III	t_2-t_3	OFF	-	D_0,D_1,D_2 and D_3



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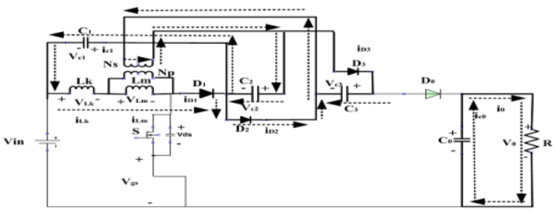

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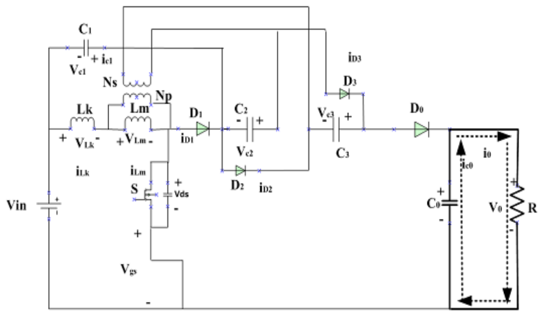


(c)

Fig.9. Current flow path of operating modes during one switching period at DCM a) mode-I, b) mode-II, c) mode-III.

Mode-I [t0-t1]: In mode-I operation, the dc voltage source Vin charges magnetic inductor and some amount of energy will be transferred to the coupled inductor secondary side. Thus, the voltage induced will be charge capacitor C2 and C3 in parallel and leakage inductor current ilk starts increasing linearly. It provides energy to the output capacitor and load R.

Mode-II [t1-t2]: In mode-II operation, the energy stored in the magnetic inductor will be transferred to the capacitor C1, C2 and C3. Then, the output capacitor C0 will give the energy to the load R.

Mode-III [t2-t3]: In mode-III operation, the energy stored in the output capacitor will be discharged to load R. Then, the magnetic inductor Lm is depleted. The mode-III will be ended at t=t3. Further, the next switching period will be started.

IV. PRINCIPLE OF BLDC MOTOR

BLDC engine comprises of the perpetual magnet rotor and an injury stator. The brushless engines are controlled utilizing a three stage inverter. The engine obliges a rotor position sensor for beginning and for giving legitimate compensation arrangement to turn on the force gadgets in the inverter extension. In light of the rotor position, the force gadgets are commutated consecutively every 60 degrees. The electronic compensation takes out the issues connected with the brush and the commutator plan, in particular starting and destroying of the commutator brush course of action, along these lines, making a BLDC engine more rough contrasted with a dc engine. Fig.10 demonstrates the stator of the BLDC engine and fig.11 shows rotor magnet plans.

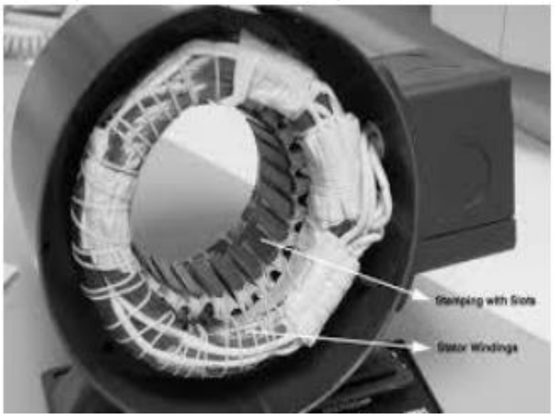


Fig.10. BLDC motor stator construction

Fig.11. BLDC motor Rotor construction.

The brush less dc engine comprise of four fundamental parts Power converter, changeless magnet brushless DC Motor (BLDCM), sensors and control calculation. The force converter changes power from the source to the BLDCM which thus changes over electrical vitality to mechanical vitality. One of the remarkable highlights of the brush less dc engine is the rotor position sensors, in view of the rotor position and order signals which may be a torque charge, voltage summon, rate order etc; the control calculation s focus the entryway sign to every semiconductor in the force electronic converter.

The structure of the control calculations decides the sort of the brush less dc engine of which there are two principle classes voltage source based drives and current source based drives. Both voltage source and current source based commute utilized for perpetual magnet brushless DC machine. The back emf waveform of the engine is demonstrated in the fig. 11. Be that as it may, machine with a non-sinusoidal back emf brings about diminishment in the inverter size and lessens misfortunes for the same influence level.

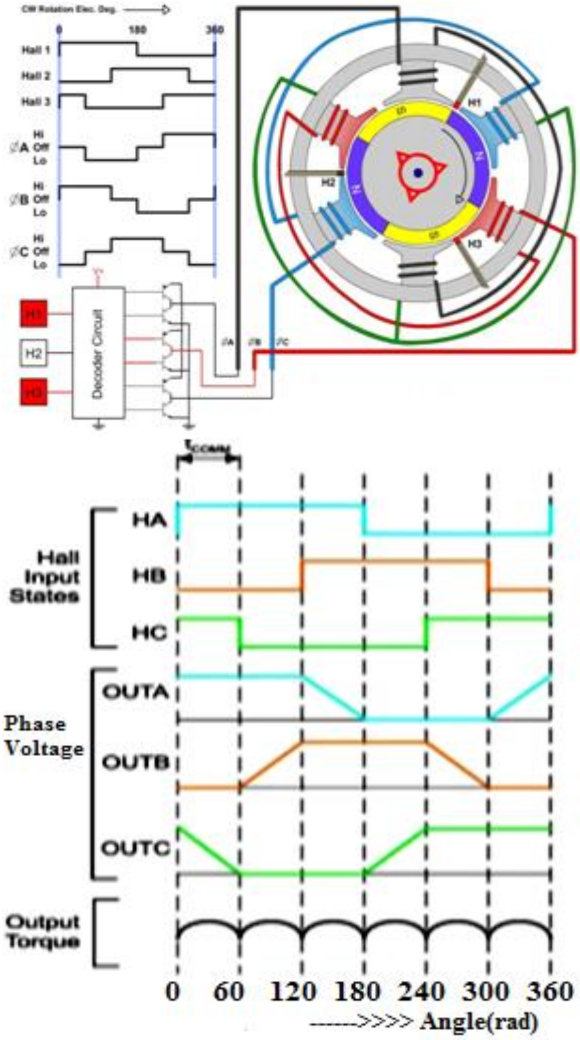


Fig.12.Four-Pole Brushless motor, Hall signals & Stator voltages Commutation, drive and winding timings.

V MATLAB/SIMULATION RESULTS

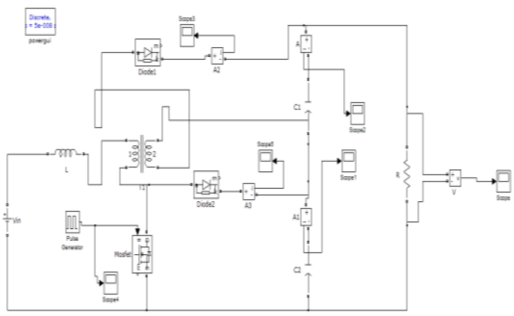
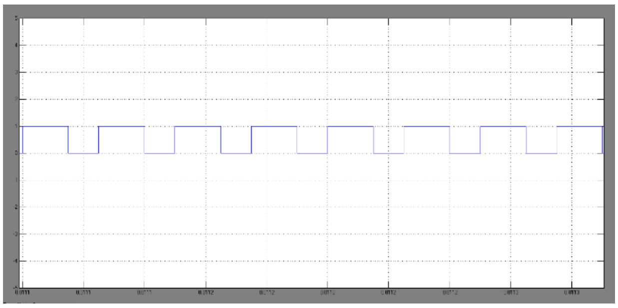


Fig.13. Matlab/Simulink model of Clamp mode coupled inductor boost converter.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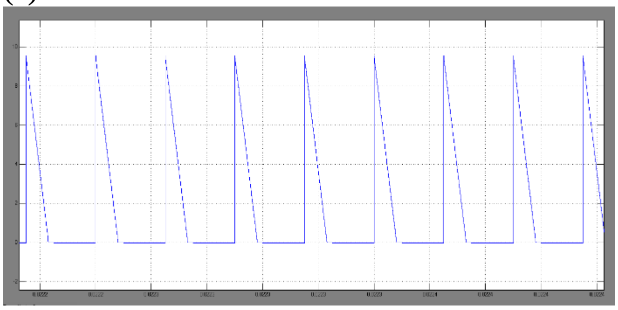
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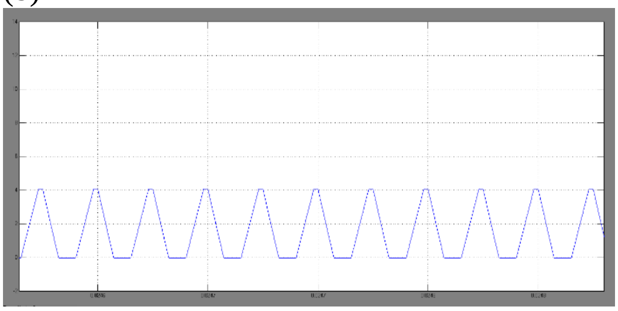
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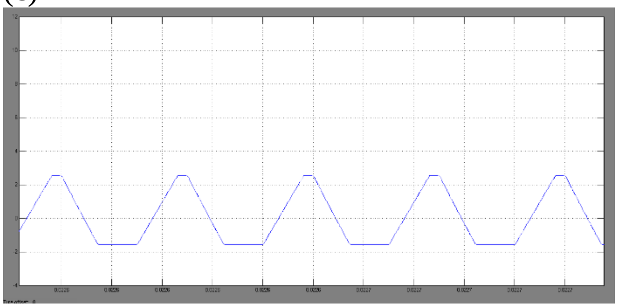
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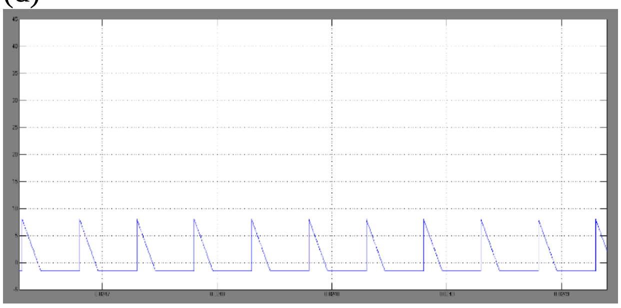
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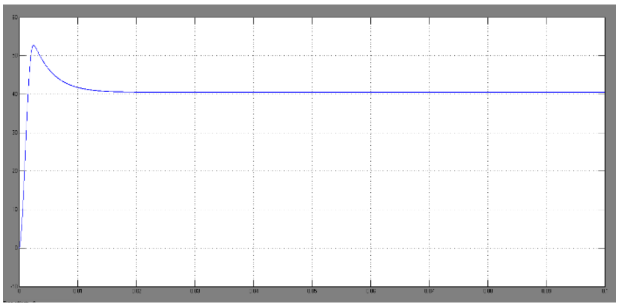

(f)

Fig.14.Simulation outputs of Clamp mode coupled inductor boost converter. (a) Switch Voltage (Vs) (b) diode1 current (Id1) (c) diode2 current (Id2) (d) capacitor current (Ic1) (e) capacitor current (Ic2) (f) output voltage.

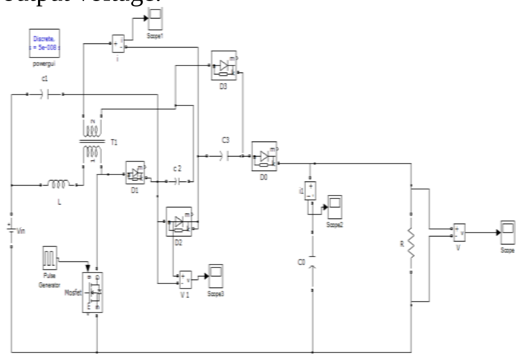
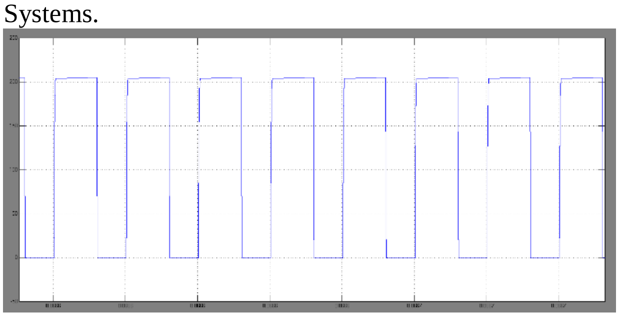


Fig.15.Matlab/Simulation Model of Proposed Converter Systems.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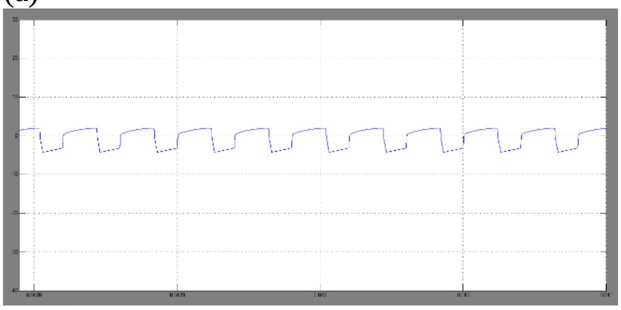
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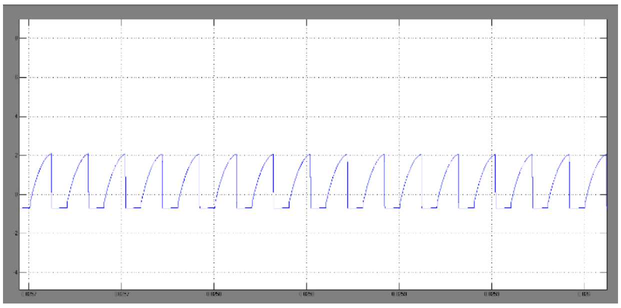

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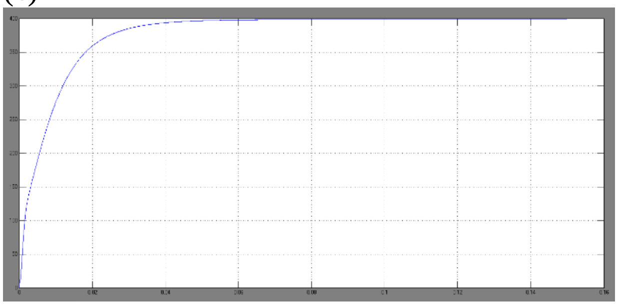

(d)

Fig.16.Simulation output of proposed converter systems (a) diode Voltage (Dv) (b) secondary Current (Is) (c) Capacitor current (Ic) (d) Output Voltage (Vo).

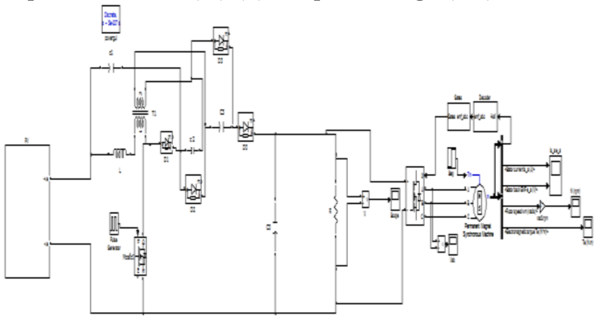

Fig.17.Simulation model of proposed converter systems with PV based converter fed BLDC Motor drive.

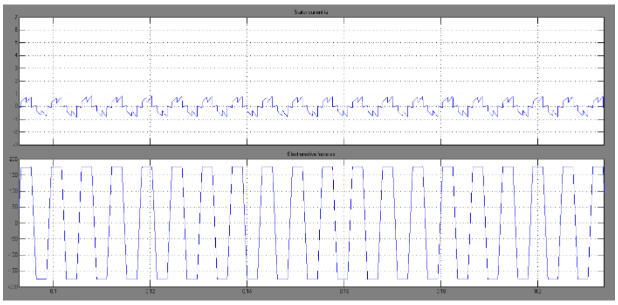

Fig.18.Stator current and Back EMF of BLDC motor.

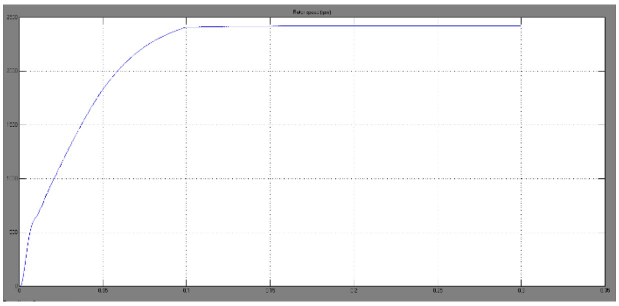

Fig.19.Speed of BLCD.

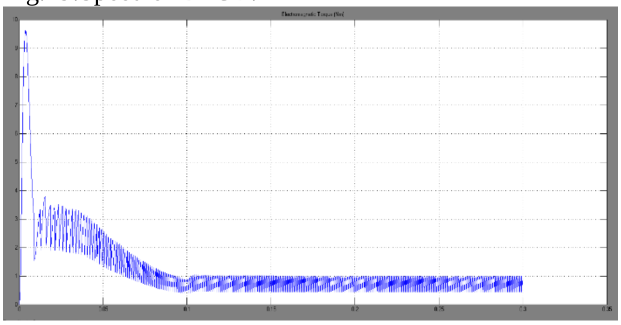

Fig.20.Electromagnetic Torque.

VI. CONCLUSION

In this work, we analyze the High step-up boost converters using coupled inductor technique. High step-up DC/DC converter with clamp mode coupled inductor and passive clamp circuit is presented for photovoltaic (PV) Applications. The principle and experimental results for a novel high efficiency, high step-up coupled inductor boost fly back converter is presented. The operation of the converter is similar to that of the active clamp fly back converter; thus the leakage energy is recovered to the output terminal and the switch voltage stress is significantly reduced. The coupled inductor technique employed to achieve the high step-up voltage gain has been investigated and verified. The converter is simulated in PSIM package and results are verified. Finally high step up dc-dc converter with active clamp mode with passive circuit is analyzed. The suggested structure consists of two capacitors and two diodes on the secondary side of the coupled inductor to achieve the high voltage gain. In addition, two capacitors are charged during the switch-off period using the energy stored in the coupled inductor which increases the voltage transfer gain. The main part of the work was involved in the development of the six step inverter and its interaction with BLDC motor. The aim was to make a model that would be simple, accurate, and easy to modify and fast running. It is believed that the goals have been reached parameters of a real BLDC motor were used and it was verified that the model performed according to the information given in the motor's datasheet.

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