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High Boost Isolated DC-DC Converter with Controller

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Abstract: This paper presents high boost isolated dc-dc converter with closed loop control to provide high voltage regulation control suitable for renewable energy source. The circuit consists of active clamp circuit and boost converter with isolated transformer. The circuit employs capacitors are charged in parallel and discharged in series by isolated transformer inductors. The active clamp circuit is used during the turn off-period to reduce the voltage spike on power switch. To achieve high output voltage gain the converter output terminal and boost converter output terminal are connected in serially with the isolated inductors with less voltage stress on controlled power switch and power diodes. PSIM software has been used for simulation. Hardware model implemented and tested in the laboratory.

Key words: Isolated DC-DC converter · Active Clamp Circuit · PSIM · High boost · Closed loop control

INTRODUCTION

High boost DC-DC converters operating at high voltage regulation are widely proposed in many industrial applications. High boost dc-dc converters are play a important role in renewable energy sources such as fuel energy systems, DC-back up energy system for UPS, High intensity discharge lamp and automobile applications. The converters require increasing low dc voltage to high dc voltage. The conventional boost converters are able to get high voltage gain with high voltage duty ratio the problem is Electro Magnetic Interference and complexity increases. In this proposed method high boost topology proposed with closed loop control. Output voltage controlled with better voltage regulation for various change in the load conditions.

DC-DC converters with coupled inductors can provide high voltage gain, but their efficiency is degraded by the losses associated with leakage inductors [2]. The solution would be the use of transformers to get the preferred voltage conversion ratio similar in forward or fly back converter the dc-isolation is no need for industrial applications. To suppress the high voltage spike on power switch non dissipative snubber circuit and active clamp circuit is used. The active clamp circuit clamps the surge voltage of switches and recycles the energy stored in the leakage inductance of the transformer [5]. The leakage energy of the coupling inductor is recycles the energy. Without wasting through active clamp, active clamp circuit consists a clamped diode and clamped capacitor. The clamped-voltage dc-dc converter with reduced revere-recovery current and switch-voltage stress. The active switch in the converter can still sustain a proper duty ratio when even under high step-up applications, reducing voltage and current stresses significantly [1, 7]. The concept of two capacitors charged parallel and discharged in series via the coupled inductor to achieve high boost voltage stress on the main switch can be reduced, analysis and implementation done in [2]. The boost converter output terminal and flyback converter output terminal are serially connected to increase the output voltage gain with the coupled inductor [3].

In this paper single controlled switch used in the flyback system with isolation for better circuit simulation and the operations analyzed. The boost converter and fly back converter outputs are integrated and improve the high voltage gain and improve the efficiency of high boost converters, these boost converters are applicable in renewable energy sources. The integrated boost flyback converter uses coupled inductor techniques to

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achieve high boost voltage with low duty and thus slope compensation circuit is disregarded [4]. The forward and flyback converters attain high voltage gain by varying transformer turns [6]. These degradations improved in the proposed circuit provided with isolation transformer. The conventional topologies to get high output voltage use flyback converters, they have the leakage components that cause stress and loss of energy that results in low efficiency [8]. These disadvantages overcome by using active clamp and the transformer turns ratio provides the high boost and isolation. The new circuit is not a used the operation integration and switched passive components as like given in [10]. Design and simulation of soft switched boost converter implemented with closed loop for SRM control applications [11].

Also analysis, control and implementation of the DC-DC converter using DSP controller described in [12]. The proposed converter advantages are the PWM Current mode control technique is used by using DSP. The low resistance transformer winding. Ferrite amorphous core used for good magnetic energy circulation. Recycling the leakage energy of the leakage inductor. Suppress the High voltage spike on MOSFET during switch turn-off period.

Proposed Circuit: The proposed circuit diagram design with four diodes, four capacitors, one, MOSFET and an ideal transformer. Proposed diagram Figure 1 consists of boost converter, coupled inductor associated with leakage inductor (L_k), magnetizing inductor (L_m) and two voltage lift capacitors. The energy of the leakage inductor is feedback to active clamp circuit, the active clamp circuit consists of one clamp diode, one clamped capacitor. The clamp circuit uses to avoid the voltage spike on MOSFET and Power diodes.

Operations: When switch is turned ON the magnetizing energy induced on secondary side of transformer V_s is connected with V_{in}, V_{c1} charge V_{c2} and simultaneously V_s charge V_{c3}. Both lift capacitors are charged and discharged equally via coupling inductor. When switch is turned off the stored magnetizing energy is released and opposite polarity is induced on secondary side of transformer (N_s) made with V_{in},V_{c2} and V_{c3} is connected in cascade and charge the capacitor C_0 and resistor. The using series connection of boost converter and flyback converter, we achieve the high output voltage gain. The proposed dc-dc converter worked in six operating modes, the six operating modes are discussed below, the mode is operated in six modes, given brief explanation about current flowing in six different modes.

Mode I: In Continuous Current Mode different switching operation of power switches and current flow path during each modes are described. In mode I switch S is turned on. Diode D_0 is turned on and diodes D_1,D_2,D_3 are turned off. The isolated transformer voltage V_s is induced on primary side the current I_{Lk} is increases shown in Figure 2. The voltage V_s is induced on secondary side and the current i_s produced.when diode i_s becomes zero diode D_0 is turned off and the currnet i_m charged linearly and increasing the magnetizing current, at the end diodes D_1, D_3 are turned on.

Mode II: In mode II switch S is still turned on, diodes D_2, D_3 are turned on and diodes D_1, D_0 are tuned off. The current waveform is shown in Figure 3. The L_m is charged with V_{in}. V_s induced on secondary of the isolated transformer V_{in} is connected with V_{c1} (voltage across C_1) charged V_{c2} (voltage across C_2) and and V_s charge with V_{c3} (volage across C_3). Simultaneously charge V_{c2} and V_{c3}. C_0 provides energy to load R.

Mode III: In mode III switch S is turned off and also diodes $D_1$and D_0 are turned off. Diodes D_2 and D_3 are turned on. The L_k and L_m of the isolated transformer releases energy to capacitor and resistor. The capacitor C_2 and C_3 are charged. The current flowing path during this switching operation shown in Figure 4.

Mode IV: In mode IV (Figure 5) switch S is turned off and diodes D_2 and D_0 are turned off, diodes D_1 and D_3 are turned on. I_{lk} decrease quickly D_0 turned on. D_3 off. The isolated transformer secondary side current i_s is decreased.

Mode V and Mode VI: In mode V the switch still turned off, diodes D_2 and D_3 are turned off, D_1 and D_0 are turned on.V_s is connected series V_{in}, $L_{m,}$ C_2 and C_3 charge C_0 and R. In mode VI L_m released energy via the seconday side of the isolated transformer inductor and provide energy to load. The seondary side voltage Vs is connected in series with voltages Vin. The current flowing path shown in Figure 6.

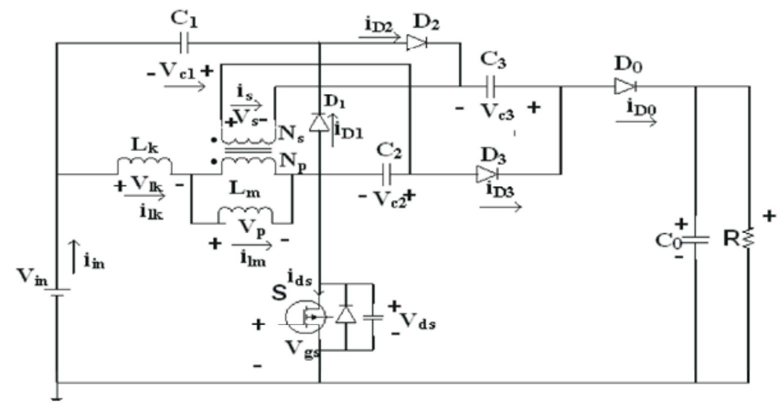


Fig. 1: Proposed high boost DC-DC Converter

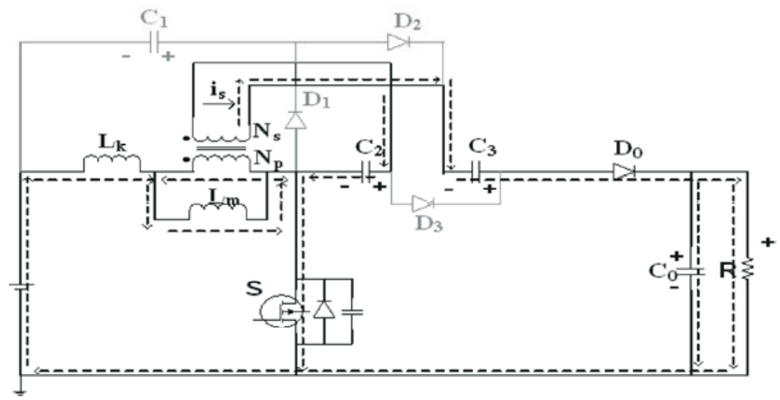


Fig. 2: Switching operation and current flowing path circuit during Mode I

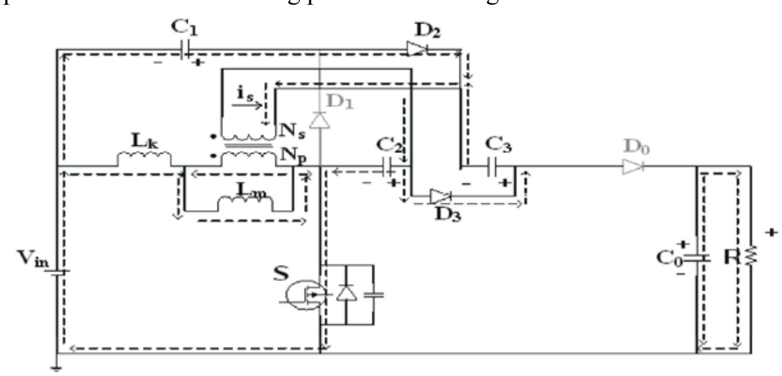


Fig. 3: Mode II Switching operation and current flowing path circuit

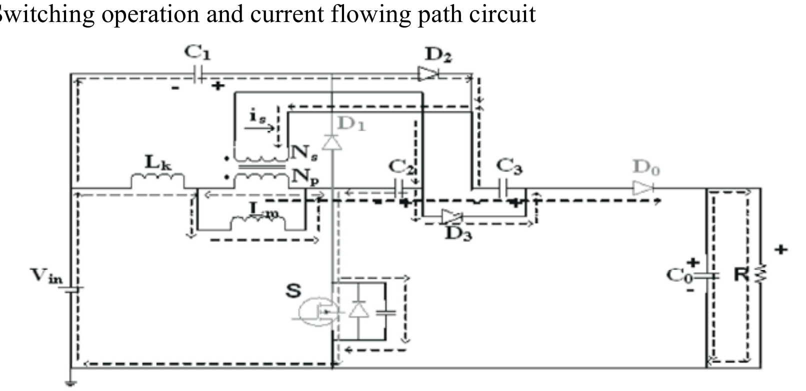


Fig. 4: Switching operation and current flowing path circuit during Mode III

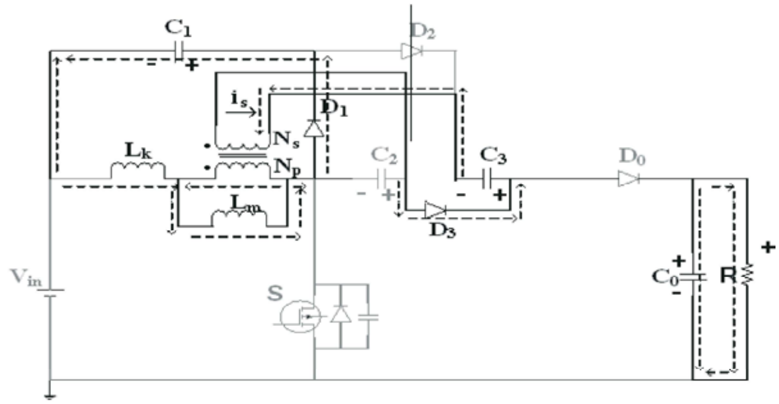


Fig. 5: Switching operation and current flowing path circuit during Mode IV

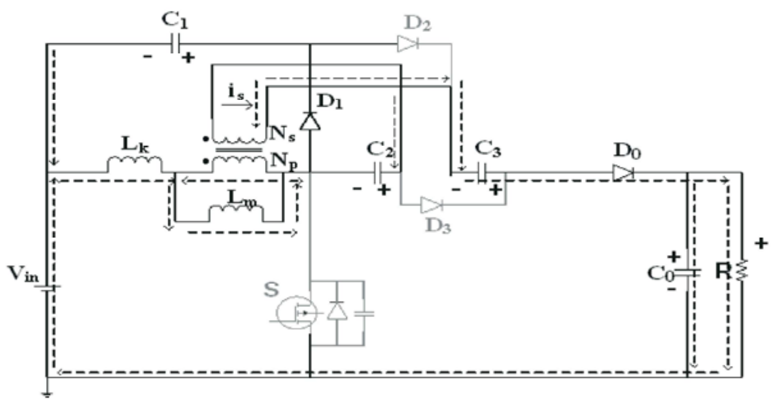


Fig. 6: Switching operation and current flowing path circuit during Mode V and Mode VI

In mode VI the switch stoll turned off. Diode D2, D3 are turned off and D1 and Do are turned on. The current flowing path shown in Figure 6. the ouput provides the boost voltage. When switch S turned on next switching perid stats.

Analysis: When switch is turn on, the equation is given as:

$$V_p = \frac{L_m}{L_m + L_k} = KV_{in} \quad (1)$$

$$V_{c3} = V_3 = nV_p = nV_{in} \quad (2)$$

The capacitor clamp voltage is given as

$$V_{c1} = V_p + V_{lk} = \frac{D(1+k)+(1-k)nV_{in}}{1-D \;\; 2} \quad (3)$$

The drain to source voltage is given as

$$V_{d3} = V_{c1} + V_{in} = \frac{D(1-K)(n-1)}{2(1-D)}V_{in} + \frac{1}{1-D} \quad (4)$$

$$V_{C2} + V_{C1+}V_S + V_{in} \quad (5)$$

$$= nKV_{in} + \frac{D(1-K)(n-1)}{2(1-D)}V_{in} + \frac{1}{1-D}V_{in} \quad (6)$$

The output voltage (V_o) can be written as according to the above equations

$$V_0 = V_{C2+}V_{C3} + V_s + V_{ds} \quad (7)$$

$$= nKV_{in} + \frac{D(1-K)(n-1)}{2(1-D)}V_{in} + \frac{2+nK}{1-D}V_{in} \quad (8)$$

The voltage gain (V_{GN}) is written as in CCM mode is

$$V_{GN} = \frac{D(1-K)(n-1)}{2(1-D)} + \frac{2+nK}{1-D} + nK \quad (9)$$

RESULTS

The proposed high boost DC-DC converter simulated using PSIM software and output voltage and output gain are described before implementing in to the hardware.

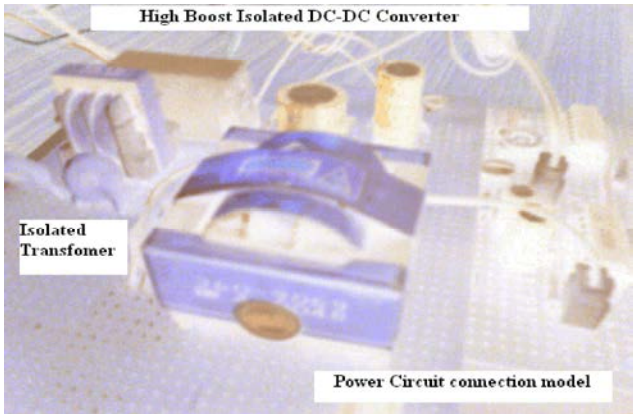


Fig. 7: Hard ware model of High Boost DC-DC Converter

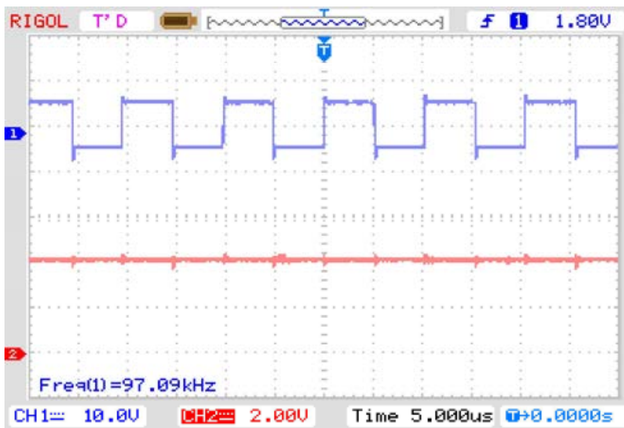


Fig. 8: MOSFET gating signal from DSP 2407

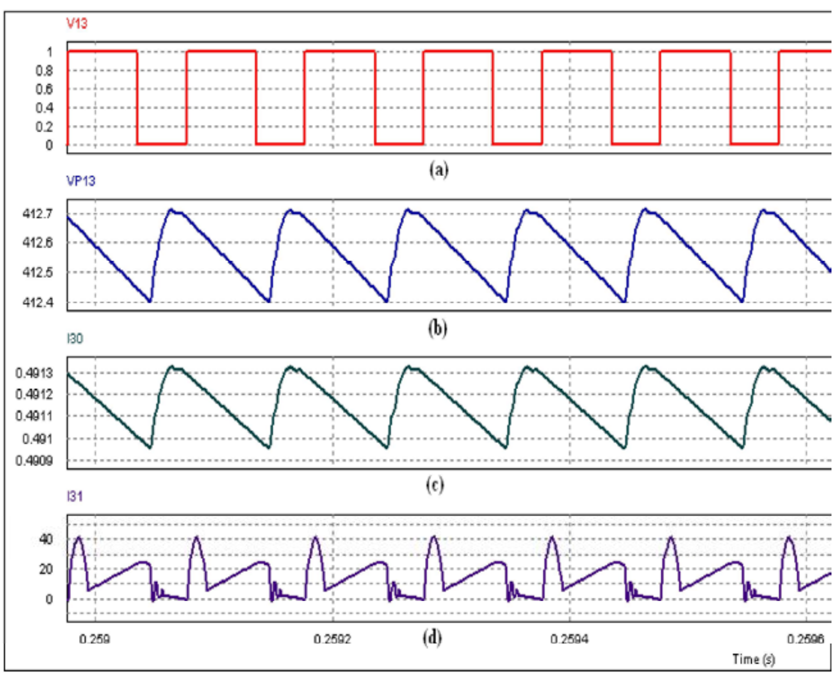


Fig. 9: Waveforms of the proposed converter
(a) Gate pulse (b) output voltage Vo (c) output current Io (d) MOSFT switch voltage

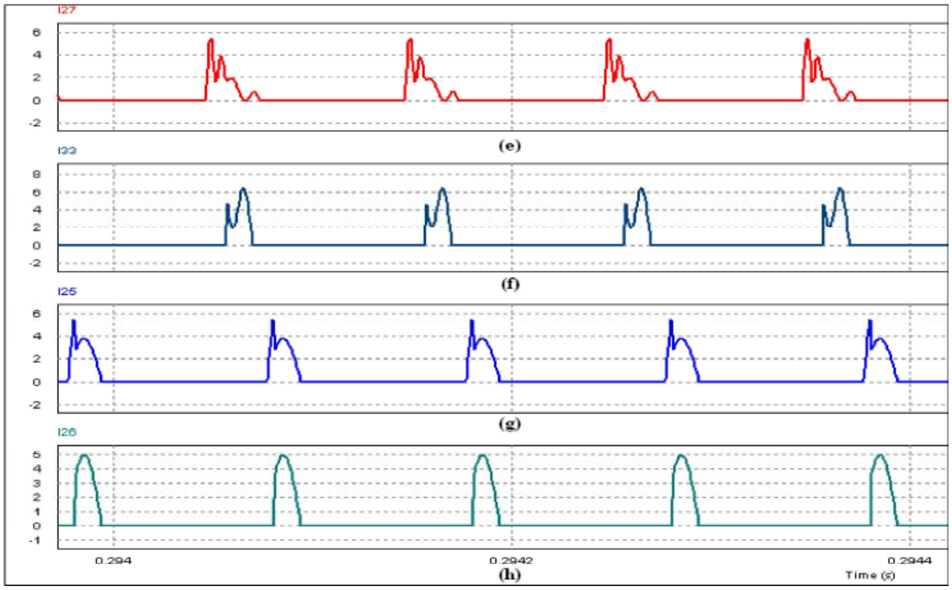


Fig. 10: Diode currents during switching operations
(e) D2 diode current (f) D3 diode current
(g) Do diode current (f) D1 diode current

Table 1: Hardware parameters

Name Of the Parameters	Values
Input voltage	10v
Output voltage	25v
MOSFET	IRF244N
Diode	1N4007
Capacitors	470uf,100uf/50v,100uf/25v
Inductors	300uh,200uh
Resistor	1k
Opto coupler	TLP250
DSP	TMS320LF2407A

Table 2: Experimental specifications

S.No.	Parameters	Spcifcation
1	Input DC voltage	20 V
2	Output DC voltage	410 V
3	Maximum output power	200 W
4	Switching Frequency	100 kHz
5	Ouput current	4.1 A
6	Output Voltage ripple	0.3V
7	Output Current ripple	0.4mA
8	Duty cycle at Full load	0.6
9	Full load resistance	840 Ohm
10	Efficeincy Half-full load	84.6%
11	Efficency at full load	79.9%

The values of the network, load is considered is as given below.

The values for the switching frequency, input voltage and the output voltage 10kHz, $20V_{dc}$ respectively used for simulation. Boost output voltage obtained $412V_{dc}$. The voltage gain K_o equal to 20.6.

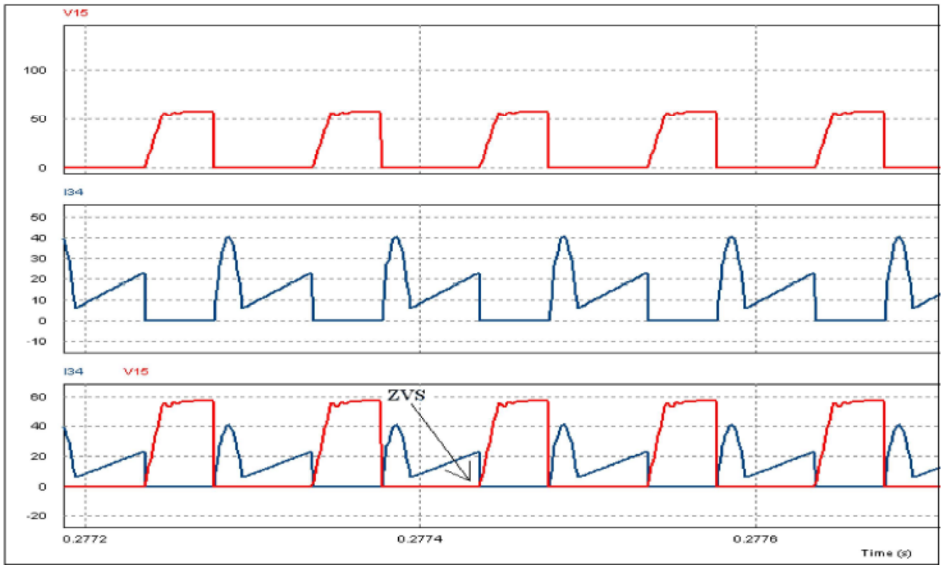
Experimental Setup: The proposed high boost isolated DC-DC converter constructed as a prototype which shown Figure 7. The input to the prototype model is given 20V from the available DC source and power controlled switch controlled through the DSP 2407 controller. The prototype model is constructed with four diode and one MOSFET. MOSFET is used because prototype model constructed for low power.

The control signal is generated from the programmed DSP controller. Depending on the desired output voltage, the controller generates control signals (PWM signal to control switch ‘S’ of the converter shown in Figure 8).

The output waveform is observed by using Digital Signal Oscilloscope and measured. The output results obtained from the prototype. The output voltage, output current, switching pulse and controlled switch voltage are shown in Figure 9.

The output currents of power diodes D_1 to D_4 are shown in Figure 10. The output voltage lifted up to 410V (Table 2). Hence it is realized with the theoretical output voltage V_o equation (8).

The experimental results show that the output voltage can be boost upto the voltage gain 20.5 and matches the theoretical value of the given equation (9). Thus, the proposed boost converter can be interface to the inverter grid at the user end. The experimental results are tabulated in Table 2.



Soft Switching
Fig. 11: Current i_{ds},Voltage across S_1 (V_{ds})

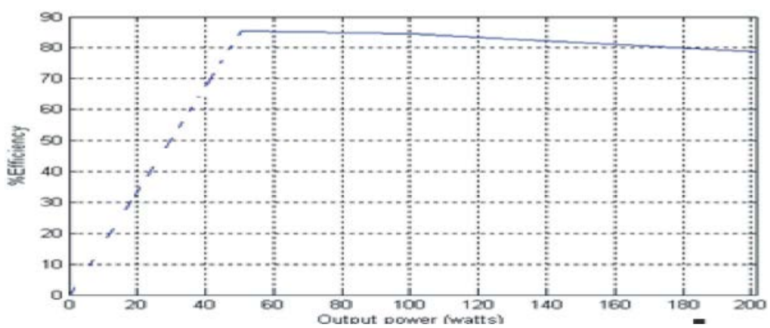


Fig. 12: Converter Efficiency Vs output power

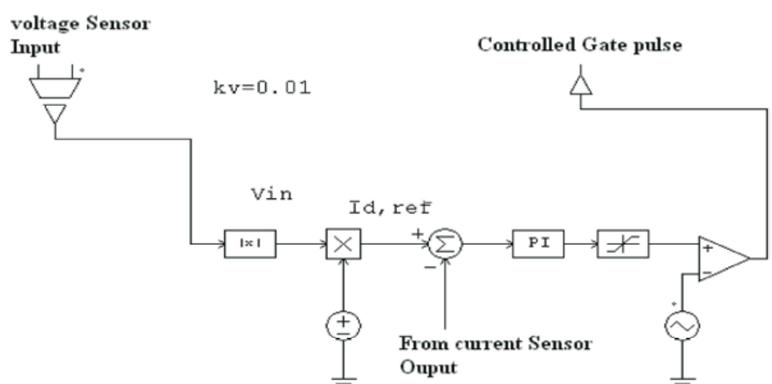


Fig. 13: High Boost Converter PI Controller

Simulation Output Waveforms: The Figure 11 shows the voltage between drain to source of the switch 1 and current through S_1. The voltage across the switch S_1 reaches zero before the gate pulse V_{gs} is applied to S_1. Then the current starts increasing through the switch. This ensures ZVS of the switch S_1 which is depicted in the arrow point in Figure 11. Efficiency of the converter calculated and plotted in the Figure 12. for various load conditions.

Closed Loop Control: The Figure 13 shows power circuit of the high voltage gain DC-DC converter model can be

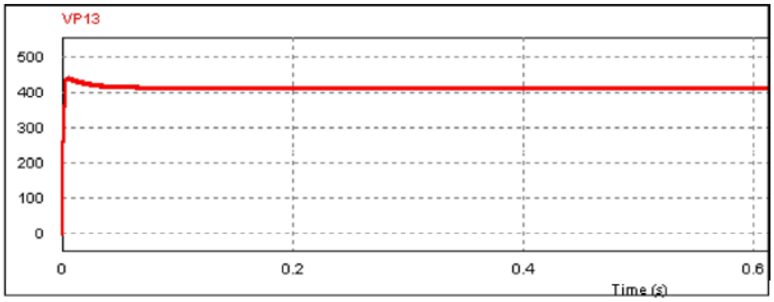


Fig. 14: Regulated Output Voltage When Load 100W

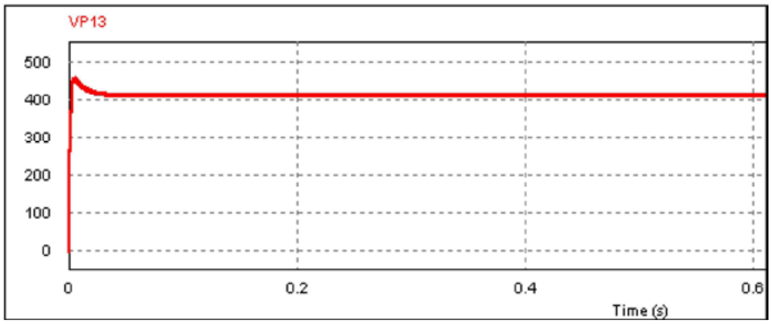


Fig. 15: Regulated Output Voltage When Load 200W

controlled by PI controller. In this circuit PI controller is designed to regulate the output voltage under load variations. The power circuit of the high voltage gain converter with PI controller is simulated in PSIM environment is shown in Figure 13.

Figure 14 and 15 shows the simulation results of the proposed boost converter in closed-loop, which gives the regulated output V_{out}=410V, for the constant an input voltage V_{in}=20V under different load conditions.

CONCLUSION

This paper explained the high boost isolated DC-DC converter with closed loop control. The use of capacitors charged in parallel and discharged in series by the coupling inductor, high boost voltage gain achieved. The steady state analysis of voltage gain discussed. The prototype circuit model tested in the laboratory. Experimental results verified with the steady state analyses output voltage and voltage gain. This proposed structure can be applicable for the renewable energy sources.

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