Design and Simulation of High Gain Boost Converter with Voltage-mode Control

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***Abstract* -** Micro grids are gaining popularity due to their easily integration with renewable energy sources (RES). High step up dc-dc converters are required to have a large conversion ratio, high efficiency. This project focuses on design and implementation of a high gain coupled inductor boost DC-DC converter and its open loop control under continuous conduction mode (CCM). High step up voltage gain is achieved through charging capacitor & discharging in series through the coupled inductor. The voltage stress on the main switch and output diode are reduced by a passive clamp circuit. A simulation of 50 Watt, 200V output voltage, 20 kHz boost converter with an input of 12V is developed.

***Keywords* -** Coupled inductor, boost converter, PV systems.

I. INTRODUCTION

Micro grids are becoming very popular because it is possible to connect them easily with a renewable energy source. There are many renewable energy sources like wind turbine energy, fuel fossil cell, photovoltaic (PV) source etc. Photovoltaic (PV) source can have a fixed range of dc supply (12-48V). It needs to boost the power and voltage capability for domestic and industrial application. Many PV cells in series can be connected to increase the voltage capability but due to different climatic conditions the overall power reduces. So, for a distributed generation system from renewable sources like PV source, there is a need of front-end converters which should not only boost the output voltage of the PV source but also should regulate a constant voltage while inter facing with the inverter.

So here use of couple inductor is introduced to reduce the spikes in voltage and transients across electronic switches of the converter. Coupled inductor methodology implemented to obtain high gain but this topology is accepted for the output power This paper views design of a simple analog controller for high gain boost converter with voltage mode control to regulate the output voltage of PV distributed system.

II. LITERATURE SURVEY

The surveys of various research papers that have contributed to achieve the high gain from lower output values obtained from renewable energy sources as photovoltaic system and also provide the guideline to work on this field. In recent years, the boost dc/dc converters have been widely used to step up the renewable energy sources in various industrial applications such as ESS, UPS, EV etc. In those applications, a boost dc/dc converter generally step up the voltage to the high voltage output.

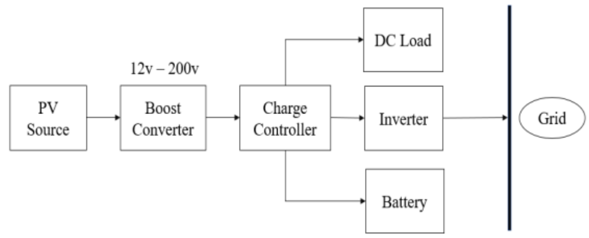

Figure 1: Block diagram of photovoltaic (PV) distributed system

For that generally, step up the voltage to the high voltage output. For that reason, to obtain a high voltage gain, many converter topologies were reported for this application. [1]-[2]

The coupled inductor-based dc–dc converter has advantages over isolated transformer-based dc–dc converter in minimizing current stress, using lower rating components and simple winding structure. Modelling procedure of the coupled inductor is described in [3].

The industrial applications, for example, uninterruptable power supply, high intensity discharge lamps for automobile headlamps, X-ray systems, TV-CRTs require high step-up voltage gain dc-dc power conversion [4].

To obtain high gain dc-dc conversion several dc-dc converters are employed which are basically divided into two categories-non-isolated and isolated converters. Non-isolated converters like conventional boost converter, cascaded converter, switched inductor and switched capacitor converters operate at high duty cycle to obtain high voltage gain [5].

Operating at high duty cycle leads to some unavoidable problems like reverse recovery problem, high conduction loss and electromagnetic interference etc. Self-lift converter, dual and multi-output dc-dc converters discussed in can almost overcome these problems. These converters can give different dc voltage levels but the voltage gains are not that much high than that of the conventional boost converter. [6]

On the other hand, isolated converters such as fly-back converter, push-pull converter, forward converter, bridge converter etc. involve transformer to isolate the input side from output side. By increasing the turns ratio of the transformer, it is possible to have a high voltage gain. But this also leads to some unavoidable problems, for example, non-linearity of the transformer, voltage spike at the switches during the off state due to the increased inductance, larger size, higher cost etc. [7].

Qun Zhao et al. developed a High-Efficiency, High Step-Up DC–DC Converters. They have used Diodes and coupled windings instead of active switches to realize functions similar to those of active clamps. [8]

Abbas A. Fardoun et al. developed an Ultra Step-Up DC-DC Converter with Reduced Switch. They have proposed a new single-switch non-isolated dc-dc converter with high-voltage transfer gain and reduced semiconductor voltage stress. The author utilizes a hybrid switched capacitor technique for providing a high voltage gain without extreme switch duty cycle, the use of a lower voltage and RDS-ON MOSFET switch to reduce cost, switch conduction and turn-on losses. [9]

Lung-Sheng Yang et al developed a Novel High Step-Up DC-DC Converter with Coupled-Inductor and Voltage-Doubler Circuits. The converter achieves high step-up voltage gain with appropriate duty ratio and low voltage stress on the power switches, and the energy stored in the leakage inductor of the coupled inductor are also recycled to the output. [10]

III. PROPOSED CONVERTER

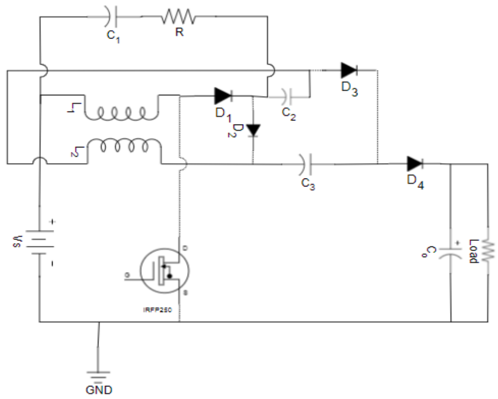

Figure 2: Proposed high gain dc-dc step up converter

The presented converter consists of dc input voltage Vin, power switch Q1, coupled inductors having primary turns Np and secondary turns Ns, one clamp clamping diode D1, one clamp capacitor C1, two intermediate capacitors (C2 and C3), two charging diodes D2 and D3, one output diode D4, and output capacitors Co that are shown in Fig 2.

Let,

V_{in}= Low input voltage

V_{L1} = Voltage across Primary winding

V_{L2} = Voltage across Secondary winding

V_{C1} = Voltage across clamp capacitor C_1

V_{C2}= Voltage across intermediate capacitor C_2

V_{C3} = Voltage across intermediate capacitor C_3

$V_O = V_{C0}$ = Output voltage across R

Ts= Switching time period of controlled switches

T_{on} = Switch ON time period of controlled switches

D = duty cycle of controlled switches (ratio of T_{on} to T_s

A. Principle of operation - There are two operating modes which are explained below.

Mode 1: (0 to t_1) ON time: In this mode, switch Q1, diodes D2 and D3 are ON .Input inductor increases and also transfers energy to the second inductor (L2) by coupling. Current in secondary winding increases in negative direction. Therefore, diodes (D2 and D3) start conducting which starts charging of capacitors (C2 and C3) simultaneously. Output capacitor supplies load. This mode get completes at $t = t_1$ when switch turns off.

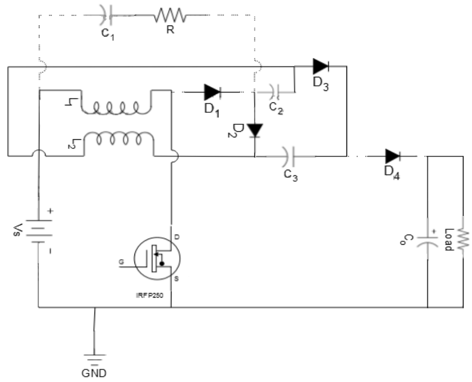

Figure 3: Equivalent circuit diagram during mode 1

Mode 2: (t_1 to t_2) Off time: In this mode, switch Q1 remains turn off. Input supply, clamp capacitor (C1), two intermediate capacitors (C2and C3) supplies energy in cascade to output capacitor and load R. This mode get completes at t = t6, when positive gate pulse is given to switch to turn on for next cycle.

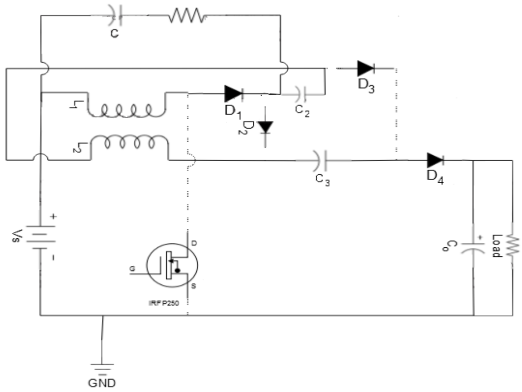

Figure 5: Equivalent circuit diagram during mode 1

B. Steady state analysis - During the mode II (for $(1 - D)T_S$ time duration) the voltage across inductor L1 (V_{L1}) and the voltage across capacitor C_1 (V_{C1}) can be written as below.

$V_{C2} = V_{C3} = n.k.V_{in}$

$V_{L1} = V_{in} + V_{C1} + V_{C2} + V_{C3} - V_{C0}$

$$Vc1 = \frac{D}{1-D}.Vin.\frac{(1+k)+(1-K)n}{2}$$

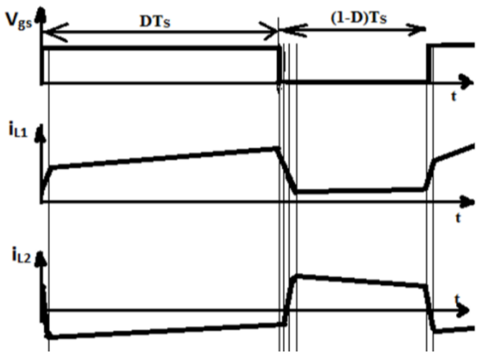

Figure 5: Key waveforms correspond to two modes of operation

Using the principle of average voltage second balance of an inductor under continuous conduction mode (CCM) the expression of the voltage gain (MCCM) is obtained as below.

$$\text{MCCM} = \frac{1+n.k}{1-D} + n.k + \frac{D}{1-D}.\frac{(1-k).(n-1)}{2}$$

The ideal voltage gain can be written as below for k = 1

$$\text{MCCM} = \frac{1+n}{1-D} + n$$

So, the converter can have highest possible gain 18.28 at the duty ratio of 64% when turn ratio n=4.

D. Design Specifications - A50Watt, 200V output voltage,20kHz high-step-up voltage gain boost converter with 12V input voltage is designed with following specifications as shown in table 1 given below.

Table No. 1 Design Specification Of The Converter

Input voltage	12V
Output voltage	200V
Output power	50W
Switching Frequency	20Khz
Duty ratio	64%
Inductance of input inductor	250μH
Inductance of secondary inductor	4000μH
Clamp capacitor	20μF
Intermediate capacitors	1.7μF
Output capacitor	40μF
MOSFET switch	IRFP250

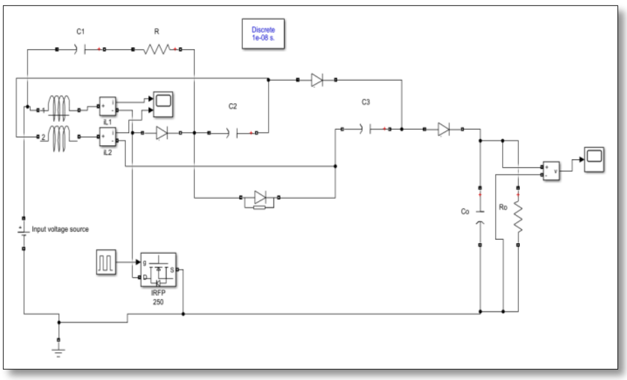
Figure 6: Simulation Model for Proposed converter

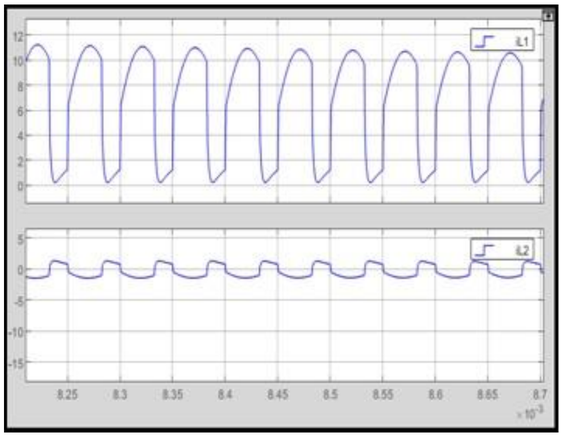
Figure 7: Key waveform of inductor current

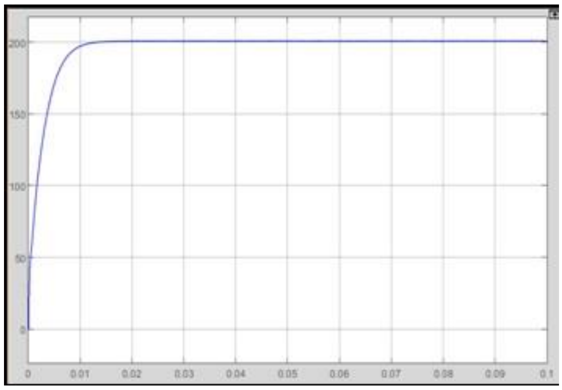
Figure 8: Key waveform of output voltage

Table No. 2 Comparision Od Conventional And Proposed Converter

Parameters	Conventional Step up converter	Proposed Converter
Voltage gain	$\frac{1}{1-D}$	$\frac{1+n}{1-D}+n$
Range of duty cycle	0<D<1	64%
Voltage stress across diode	$\frac{Vi}{1-D}$	$\frac{n.Vi}{1-D}$
Conduction loss at switches	Higher	Reduced due to use of coupled inductor
Output voltage ripples	0.29%	1%
Input inductor current	Low	High due to coupled inductor

IV. CONCLUSION

This paper presents design and implementation of a high gain dc-dc boost converter for PV systems. The various techniques like boost converter, buck-boost converter, 3 state switching have been used for PV systems. The drawback of such technique was high input ripples and maximum efficiency was achieved at extreme duty ratio. The conduction losses switch losses were also the factors affecting the performance of system slightly. The proposed system high step up gain DC-DC converter has a high gain coupled inductor boost DC-DC converter, the model is operating at high gain. Also, less input current ripples are seen in the graph, that means it minimize the input current ripple. By implementing high gain coupled inductor high output voltage is achieved which was also the drawback of system. It has been observed that the system provides a maximum output value with high duty ratio. In the above simulation converter can have highest possible gain of 18.28 at duty ratio of (64%) when turns ratio is equal to 4.

V. REFERENCES

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