Analysis & Simulation of DC-DC Interleaved Boost Converter Using Renewable Energy (PV) System

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Abstract **- Renewable energy is derived from ordinary resources that are replenished constantly. The commonly used renewable energy systems include photovoltaic cells and fuel cells. A suitable DC-DC converter is planned for highly efficient renewable energy systems. Interleaved Boost Converter (IBC) topology is discussed in this paper for renewable energy applications. The advantages of interleaved boost converter compared to the classical boost converter are low input current ripple, high efficiency, faster transient response, reduced electromagnetic emission and improved reliability. In this paper a two phase's interleaved boost converter is designed for photo voltaic generation system using MATLAB / Simulink software.**

Keywords- **Boost converter, Interleaved Boost Converter, Solar Energy (PV) System, MATLAB / Simulink Software.**

I. INTRODUCTION

Renewable energy based technologies, such as solar and wind, are receiving increased interest for electricity production because they are non-polluting and do not derive from finite resources. Solar photovoltaic (PV), in particular, has found numerous applications, ranging from small, standalone systems to utility-scale; grid-connected power plants [1]-[2]. At the end of 2015, grid-connected PV capacity in the US reached almost 25.6 GW [3]. Renewable energy sources with low output voltage, such as the fuel cell stacks and photo-voltaic (PV) generation system, have received a great attention in research fields because they appear to be the possible solutions to the environmental problems[4]-[6].

The voltages produced by renewable energy sources such as photovoltaic (PV) arrays and fuel cell stacks are generally low. These voltages need to be increased to high voltages for certain applications. One of the challenges in the development of renewable energy systems, which are based on photovoltaic modules and fuel cell stacks, is the conversion of relatively low DC voltage to high DC voltage [7].

DC-DC converters are an important component as power electronics interfaces for photovoltaic generators and other renewable energy sources. Most renewable power sources, such as photovoltaic power systems and fuel cells, have quite Low-voltage output and require series connection or a voltage booster to provide enough voltage output [8]-[11].

Figure 1 shows a block diagram of a standalone PV system.

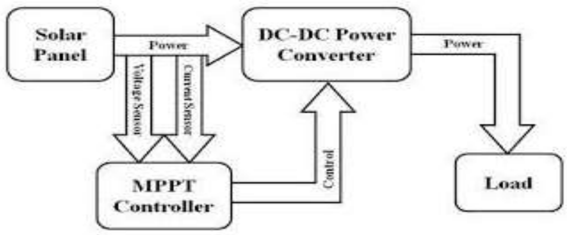

Figure 1: Block diagram of a standalone PV system.

Here stand-alone PV system applications, it is of much significance that maximum power is extracted from the solar panel and delivered to the load whenever possible. Nature decides whenever irradiation and temperature changes, hence the output power of the solar panel might change at any time.

Owing to the non-linear nature of the PV output power, it is of essential that its maximum power which can be obtained from it is tracked at all times and fed to the load. An MPPT is used for tracking the PV maximum power under any operating condition and the dc-dc boost converter is used to step up the voltage and fed to the load. The two main types of dc-dc converter topologies that are predominantly employed in stand-alone PV system are the conventional dc-dc boost converter and interleaved dc-dc boost converter.

One of the two dc-dc boost converters aforementioned offer better efficiency under weak operating point of the solar panel, whilst the other offer improved efficiency under strong operating point of the solar panel [12].

The standalone PV system developed can be used to power TVs, Compact Disc (CD) players, Laptops, etc.

II. DESIGN OF A DC-DC BOOST CONVERTER

The conventional boost converter which could be used in many power electronic applications, for example in regulated DC power supplies, and in photovoltaic systems. The value to stepping up a low DC input voltage to higher DC output voltage of desired load. The converter has two mode of current operations, discontinuous current mode (DCM) and continuous current mode (CCM). In power applications, the conventional boost converter is able to operate in any mode of current operation under changed power levels, and with each mode has variance characteristics.

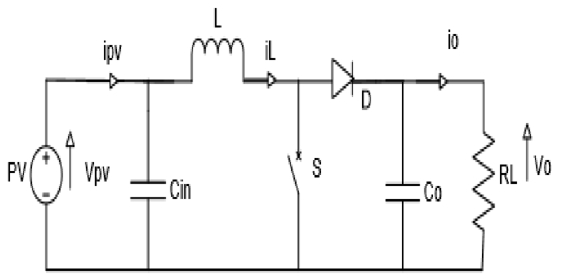

Figure 3: Circuit diagram of Conventional Boost Converter

Conventional boost converter has a simple circuit and low cost. The disadvantages of conventional boost converter are high ripple current on active and passive components, large voltage stress for power switches, and require a large capacitor value to keep the output voltage steady. This difficulty can be solved by using interleaved boost converter which is another power boost converter circuit.

The circuit design of interleaved boost converter as shown in Figure 3, is used to improve the power processing capability and to operate the solar systems with its maximum power.

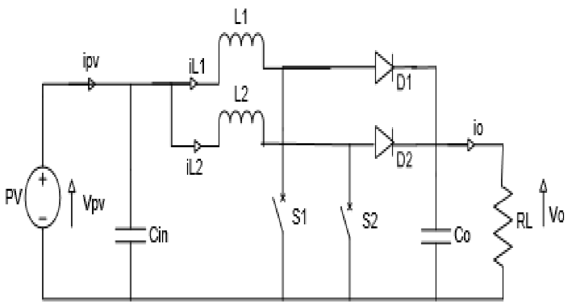

Figure 3: Circuit diagram of Interleaved Boost Converter

Interleaved step-up converter topology works with binary branches operating 180 degree out of phase from each other. Generally, each phase operates in the same fashion as the conventional boost converter previously described. When switch two turns on, the current ramps up in inductor two, with a slope depending on the source voltage that stores energy in inductor two, the diode two is off during this time since the output voltage is higher than the input voltage. When switch two turns off, diode two connect and deliver energy to the output capacitor and the load, and current of inductor two ramps down with a slope dependent on the difference between the source and load voltage. One half of a switching period later, switch one also will turn on to complete the same cycle of events. The advantage of the interleaved boost converter gives low ripple power at the output and input stages due to an effective increase in switching frequency, hence the interleaved has chance to minimize output and input capacitor filters which will be relatively large if conventional boost converter is used. Additionally, greater efficiency level achieved by forcing the input current to move and shared in the two limbs, substantially decreasing (I^2R) power losses. Moreover, the converter gives low stresses on the passive and active components due to current split which rise power process capability [13].

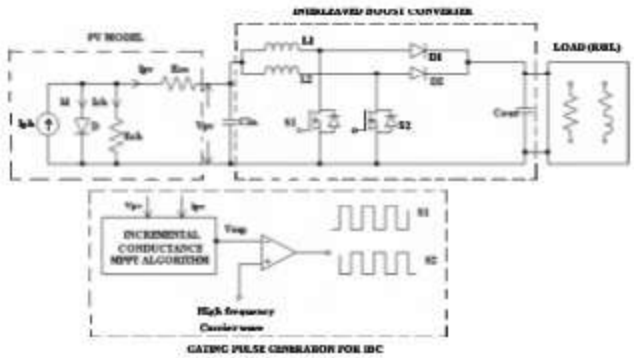

Figure 4: Schematic of Interleaved Boost Converter with PV System

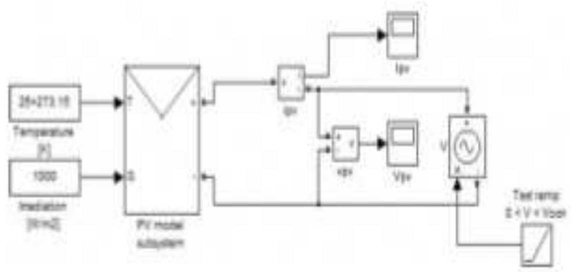

Figure 5: MATLAB subsystem to represent PV model

PV Panel (SOLAR Panel)

Iscn = 2.55A; Vocn = 21.24V; Imp=2.25A; Vmp=16.56V; Pmp = 37.08W

Converter

Cin=100µF; Cout = 100uF; L=200µH; Lm_l = 9.7mH; Lm_2= 9.7 mH ; R1oad=100Ω; Z_{RL} load= 106.5 **Ω** ;β= 0.65

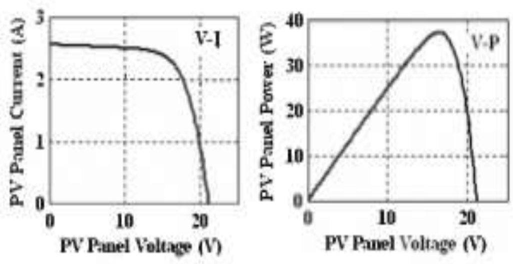

Figure 6: Characteristics of PV system

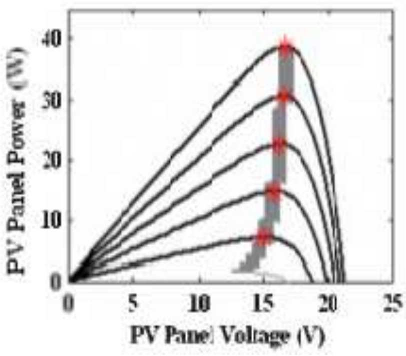

Figure 7: Simulation of INC algorithm

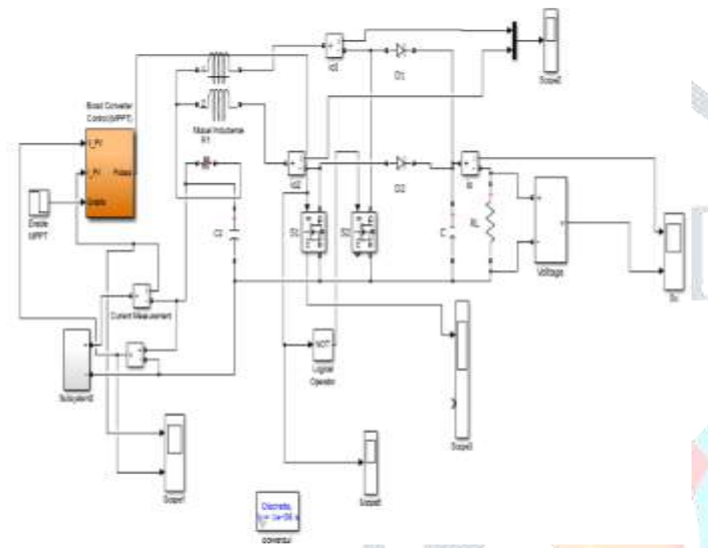

Figure 8: Simulation Model of Interleaved Boost Converter Using MATLAB / Simulink

Therefore to minimize the ripples, size and cost of input filter a two phase Interleaved boost converter fed photovoltaic generation system is simulated using MATLAB/Simulink software in this paper.

The advantages of interleaved boost converters are reducing input current ripple, increasing efficiency, improving reliability etc. The number of switching devices, number of inductors and diodes are same as the number of phases used in the circuit [14]. The circuit diagram of proposed two phase interleaved boost converter is shown in figure 6. The input voltage is 100-300V [15]. Each leg of the converter has the switching frequency of 20 KHz. The gating pulses of the power electronic switches are shifted by,

$$360^\circ/n$$

Where 'n' is the number of phases

$$360^\circ/2 = 180^\circ$$

III. PV SYSTEM WITH MPPT

In this paper, an analysis of a PV-fed interleaved boost converter (IBC) has studied. An IBC with two boost converters connected in parallel has considered for this work. The component of the studied system include the PV panel, a boost converter (conventional or IBC), load, maximum power point tracking (MPPT) using the Incremental Conductance (IC) algorithm method.

IV. MAXIMUM POWER POINT TRACKING

Maximum Power Point Tracking, frequently referred to as MPPT, operates Solar PV modules in a manner that allows the modules to produce all the power they are capable of generating. MPPT algorithms are used to obtain the maximum power from the solar array based on the variation in the irradiation and temperature. Among several techniques, the Incremental Conductance (IC) algorithm is the commonly applied algorithms. The flow chart is explaining Incremental Conductance (IC) method as

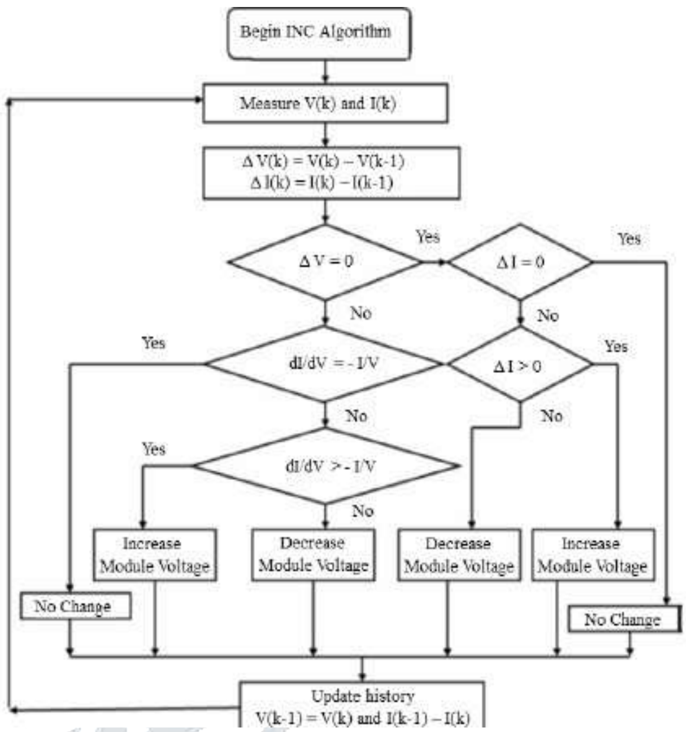

Figure 9: Flow chart for INC algorithm

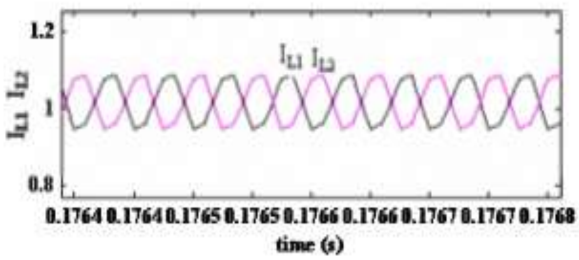

Figure 10: Current through coupled inductors of IBC

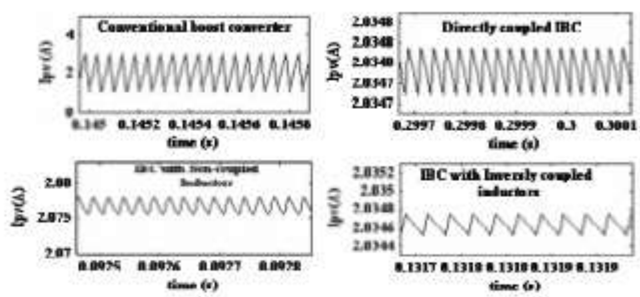

Figure 11: Input Current ripple Comparison

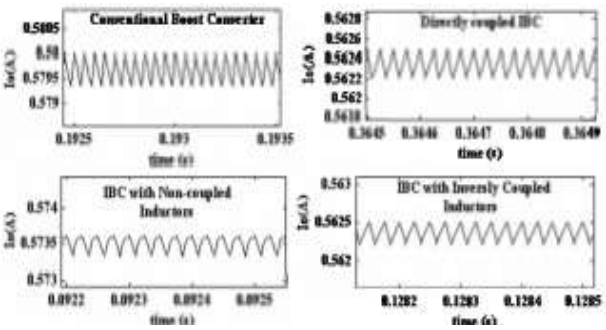

Figure 12: Output Current ripple Comparison

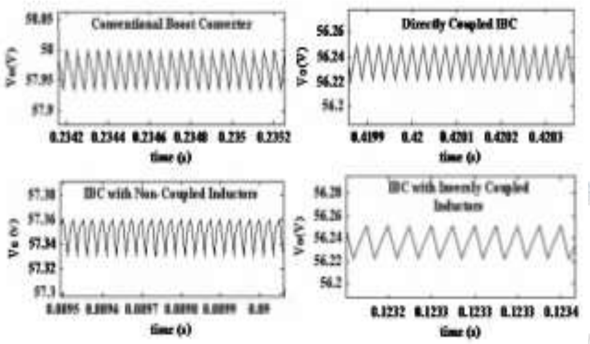

Figure 13: Output Voltage ripple Comparison

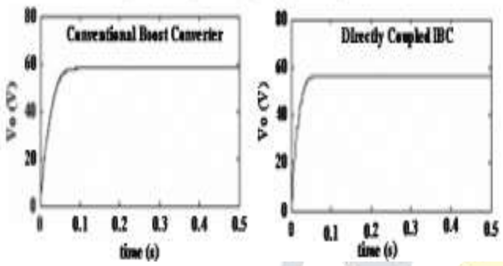

Figure 14: Voltage comparison including transient period

IV. SIMULATION RESULT

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SIMULATION RESULTS FOR R LOAD

Type of Converter	Input			Output		
	V	I	P	V	I	P
Conventional Boost	17.76	2.02	35.87	58	0.58	33.64
IBC with non-coupled inductors	17.53	2.076	36.41	57.36	0.574	32.91
IBC with directly coupled inductors	17.7	2.035	36.02	56.22	0.562	31.61
IBC with inversely coupled inductors	17.71	2.035	36.02	56.23	0.562	31.62

TABLE 2
SIMULATION RESULTS FOR R-L LOAD

Type of Converter	Input			Output		
	V	I	P	V	I	P
Conventional Boost	17.75	2.022	35.89	57.97	0.579	33.59
IBC with non-coupled inductors	17.53	2.076	36.41	57.34	0.573	32.88
Directly coupled IBC	17.7	2.035	36.02	56.23	0.562	31.61
IBC with inversely coupled inductors	17.7	2.032	36.02	56.23	0.562	31.62

TABLE 3
COMPARISON OF RIPPLE PERCENTAGE FOR R LOAD

Type of Converter	Input Ripple Current	Output Ripple Current	Output Ripple Voltage
Conventional Boost	96.53%	0.121%	0.112%
IBC with non-coupled inductors	96%	0.05%	0.05%
Directly coupled IBC	0.004%	0.053%	0.051%
IBC with inversely coupled inductors	0.009%	0.05%	0.068%

TABLE 4
COMPARISON OF RIPPLE PERCENTAGE FOR R-L LOAD

Type of Converter	Input Ripple Current	Output Ripple Current	Output Ripple Voltage
Conventional Boost	76.7%	0.08%	0.11%
IBC with non-coupled inductors	96.08%	0.022%	0.07%
Directly coupled IBC	0.004%	0.08%	0.05%
IBC with inversely coupled inductors	0.014%	0.08%	0.05%

From Figures (11) to (13) and from the tables, it is found that; ripple percentage is less in directly coupled IBC which reduces the filter size. Moreover from Figure 14, it is shown that IBC has faster transient response compared to conventional boost converter.

V. CONCLUSION

In this paper analysis of IBC converter using renewable energy (PV) system has been carried out. To extract the maximum power, boost converter with INC algorithm is used. To reduce the ripple IBC with noncoupled, coupled and inversely coupled inductances have been designed and their performances have been compared in terms of percentage of reduction in ripple in both source and load sides. It is found that directly coupled IBC reduces ripples compared to other arrangements and also it reduces the higher value of input filter capacitance requirement. In this paper simulation results have been presented for low voltage levels, but the concept can be extended to higher voltage levels with same inferences for industrial purpose.

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