Indian Journal of Communication Engineering and Systems (IJCES)
Vol.2.No.2 2014 pp 54-59.
Available at: www.goniv.com
Paper Received: 04-04-2014
Paper Accepted: 14-04-2014
Paper Reviewed by: 1. R. Venkatakrishnan 2. R. Marimuthu
Editor: Prof. P.Muthukumar

NON ISOLATED HIGH GAIN TWO INDUCTOR BOOST CONVERTER FOR SOLAR PV APPLICATIONS

N.Venkatarama[1], R.Anand[2], Dr.I.Gnanambal[3]
Department of Electrical and Electronics Engineering
Government College of Engineering, Salem-11, Tamilnadu, India.
venkatvarsha@yahoo.com

ABSTRACT

A DC-DC Boost Converter with an input Boost transformer with constant frequency controller is described. The converter is also designed for a high gain which is suitable for solar power application to operate loads without back-up Batteries. At the output, reasonable regulation is also assured for wide change in load and also to the wide change in input power. An EMI filter and a MPPT tracker at the input assures the maximum power utilisation of PV modules.

Keywords— Boost Converter, High Gain, Regulation, Constant frequency control, (TIBC) Two Inductor Boost Converter.

1. INTRODUCTION

Conventional Boost Converters use a single inductor with single or parallel connected switches. When they are used in High Current and High Power applications, the efficiency and the regulation turn to be poor. This is mainly due to under- utilisation of the available power. Many successful attempts are already made to address such problems. As an example, an interleaved boost topology is well suited for high power and high gain applications. But they all exhibit a reasonable performance only in Continuous Conduction Mode. So, eventually before designing a converter we are to be sure about the Load or Load range which is going to be handled. Though the converter can be operated in Discontinuous Current Mode, it generates in lot of EMI and Audible noises. The EMI filter at the input helps to filter such noises.

Conventional Two Inductor Boost Converter with an auxiliary transformer is studied and the simulated results are produced.So far, many numbers of converters with various topologies have been studied. Almost in every boost design the input DC voltage is kept almost constant. This type of converters exhibit poor regulation when connected to a solar PV input where there are wide input power variations. Finally a new type of Two Inductor Boost Converter is selected and studied along with a P&O MPPT controller and an EMI input filter. Carefully selected switching frequency and an Isolation transformer with a voltage doubler at output brought a better result.

The conventional Two Inductor Boost Converter is shown in Fig.1. On analysis and in simulation it exhibited some interesting properties. The simulated results are shown in Fig.2. From the results it is evident that the voltage stress across the switches are fifty per cent as in the case of a single inductor booster. The input and out current ripples are considerably reduced with lesser filter capacitor value.

However there is a limitation with the conventional circuit, is the poor regulation, i.e. it is unable to cope up with wide load variations.Fig.2.explains with the key waveforms, the currents through the inductors L1 and L2 increase with S1 and S2 ON and decreases with S1 and S2 OFF.

So, it is evident that we cannot allow overlap conduction in these types of converters as they will only increase the switching losses. So, the maximum duty cycle has to be limited to 50% only. The proposed converter eliminates such problem and duty cycle allows the overlapped conduction.

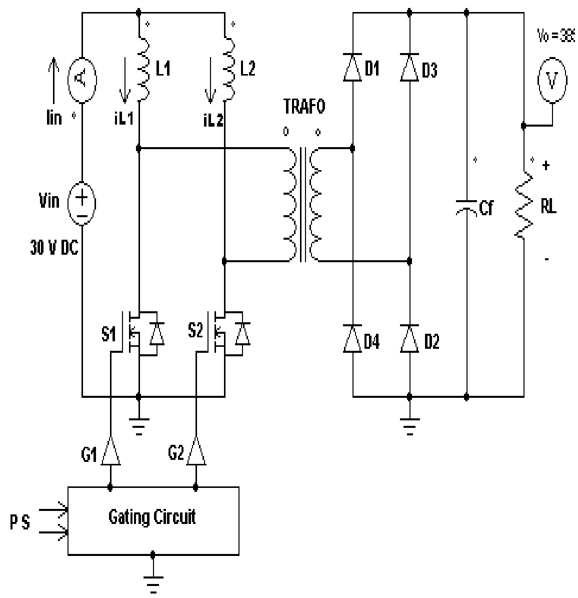

Fig. 1 Conventional Two Inductor Booster

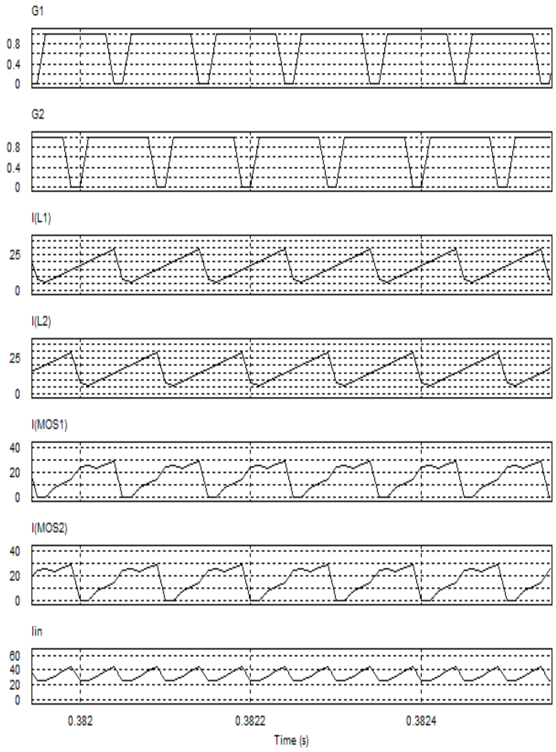

Fig. 2. Key Waveforms of Conventional Two Inductance Boost Converter (over lapped CCM)

Therefore to maintain a reasonable regulation limits, the switching frequency must be increased. This will result in more switching losses and more EMI. Looking into the Auxiliary transformer, it can be used both for isolated and non-isolated versions.

2. ANALYSIS OF OPERATION

A non-isolated version of a Two Inductor Boost Converter is shown in Fig.3.

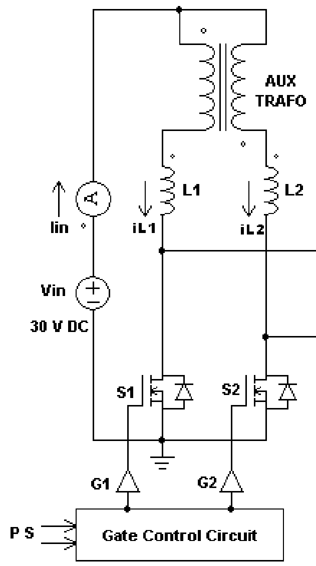

Fig. 3 Proposed Two Inductor Booster with Auxiliary Transformer.

The input end consists of two switches S1 & S2, two inductors L1 & L2, an auxiliary transformer ATR. The output end has a bridge made up of two diodes D1 & D2 and two electrolytic capacitors Cf1 & Cf2 to have more voltage gain. The load is a pure resistor RL to make it simple.Fig.4. a simplified version of the circuit explains how the current flows are with arrow marks [1]. The auxiliary transformer is considered to be an ideal one and modelled as two separate inductors and their mutual inductances.

The Cf1 & Cf2 are considered large enough to act as ripple filters simultaneously. All semi-conductor devices used in this circuit is considered to be ideal i.e. they have Zero impedance while they are ON and Infinite resistance while they are OFF.

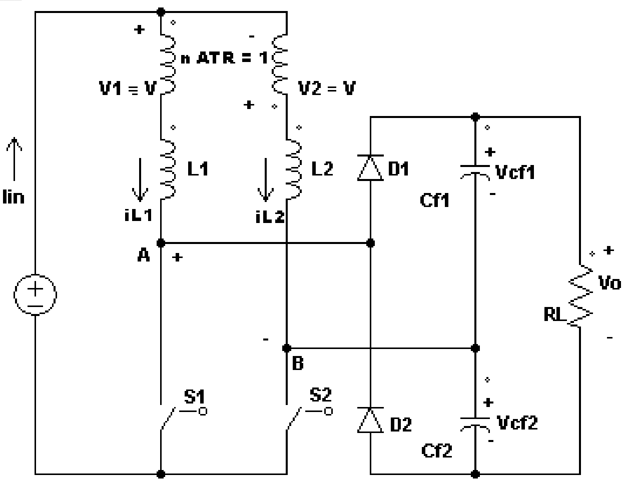

Fig.4 Simplified Circuit model of proposed converter.

Fig.5. (a), (b), (c) and (d) shows the topological stages of conduction in different modes. i.e. both S1 and S2 ON, only the S1 ON, only the S2 ON etc. From the key waveforms shown in Fig. (6).is for the

simulation of the circuit shown in Fig. (3).The entire circuit is analysed in parts and is compiled in Fig. (6).

From Fig. (4). it can be seen that the inductors L1 and L2 are in series through Auxiliary Transformer due to its 1:1 (Unity) turns ratio. Therefore during the time that both S1 and S2 are ON i.e. the interval to-t1, Fig.5 (a), the inductor currents continue to rise and the rate of raise of current through inductor is calculated as per equations (1) and (2).

$$V_{in} = V_1 + L_1\frac{diL1}{dt} \qquad (1)$$

And

$$V_1 + L_1\frac{diL1}{dt} = -V_2 + L_2\frac{diL2}{dt} \qquad (2)$$

The rate of raise of current will be same if L1 = L2. So,

$$V \quad \frac{2- \;\; 1}{2 \;\; 1} V_1 \qquad (3)$$

Where, V = V1 = V2 because the turns ratio is Unity for the auxiliary transformer.
If both the inductances are equal then,
L = L1 = L2, and v = 0, i.e. output is Zero.

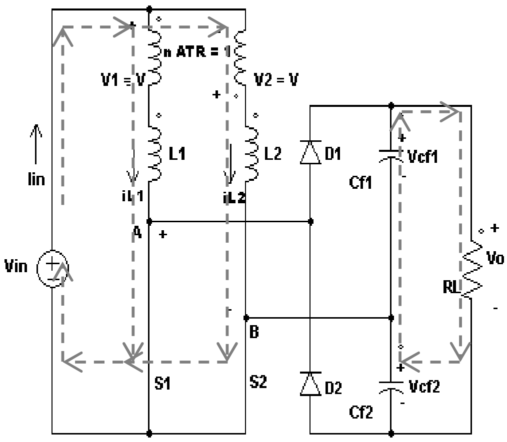

Fig.5. (a) $t_o - t_1$ [S1 & S2 ON]

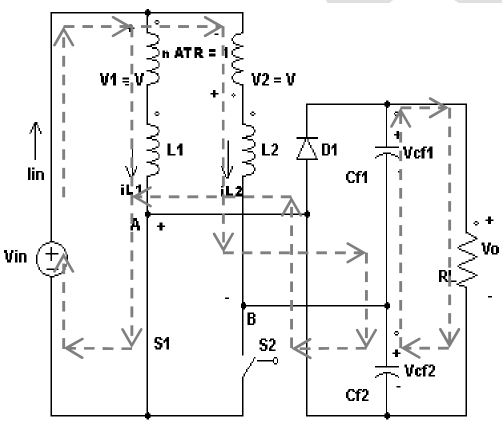

Fig.5. (b) $t_1 - t_2$ [S1 ON & S2 OFF]

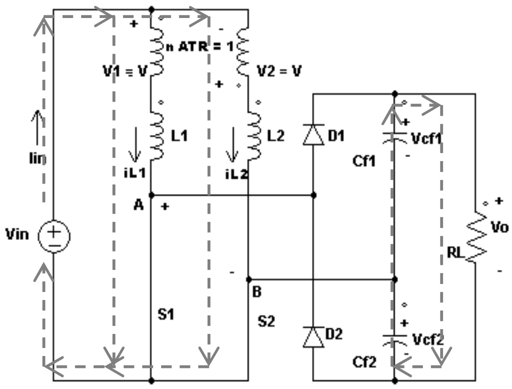

Fig.5. (c) t_2- t_3 [S1 & S2 ON]

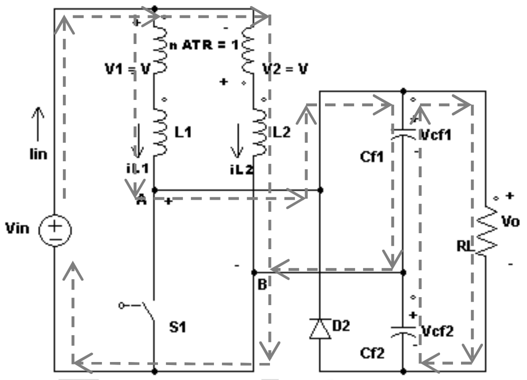

Fig 5. (d) $t_3 - t_4$ [S1 OFF & S2 ON]

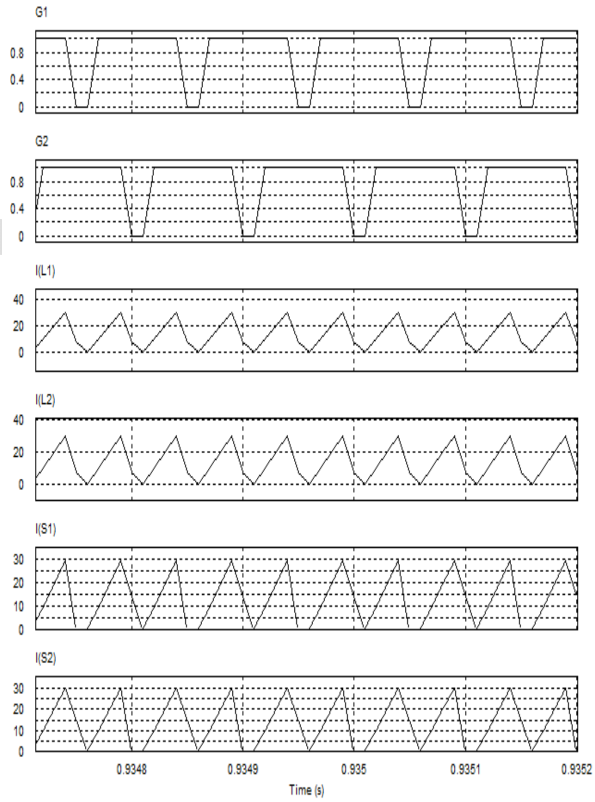

Fig.6. Different topological stages of conduction.

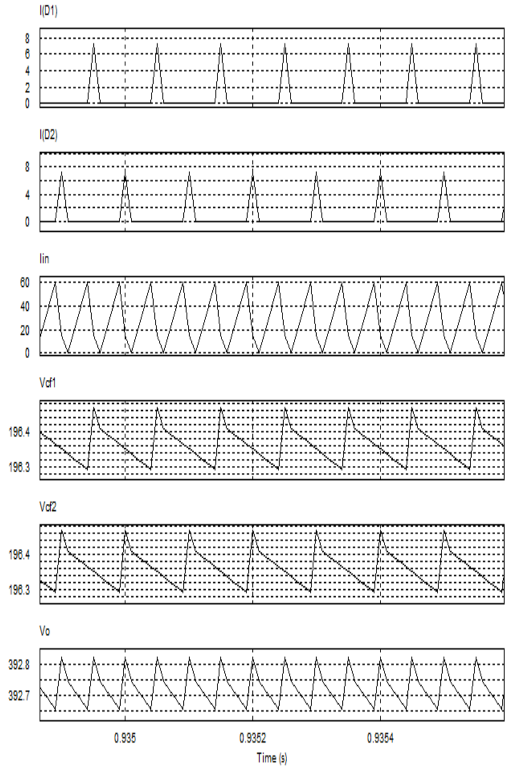

Fig.7. Key Waveforms of proposed converter (over lapped CCM)

If v = 0, then the equations (1) through (3) becomes,

$$\frac{diL1}{dt} = \frac{diL2}{dt} = \frac{V\ \ -}{1} = \frac{V\ \ \ \ \ \ 1}{2} \quad (4)$$

Also

$$\frac{diL1}{dt} = \frac{diL2}{dt} = \frac{i}{L} \quad (5)$$

So, from the above equations, the output is decoupled from input when both the switches are ON, Fig.5 (a), and the diodes D1 and D2 are reverse biased. The Cf1 and Cf2 now are already charged to Vf1 and Vf2 respectively from previous cycles, so

The output becomes Vo = Vf1 + Vf2 and this starts discharging. When S2 is turned OFF, the inductor L2 current starts discharging through D2 as shown in Fig.5 (b). Simultaneously the energy stored in capacitor Cf2 also starts discharging. The current discharge rate is given by the following equations,

$$V_{in} = V_1 + L_1\frac{diL1}{dt} = V + L1\frac{diL1}{dt} \quad (6)$$

and

$$V_{AB} = -V_{cf2} = -L_1\frac{diL1}{dt} - V_1 - V_2 + L_2\frac{diL2}{dt} = -2V \quad (7)$$

From equations (6) and (7) and taking L = L1 = L2, becomes

$$V = \frac{V\ \ f2}{2} = \frac{V\ \ f}{2} \quad (8)$$

And

$$\frac{diL1}{dt} = \frac{diL2}{dt} = \frac{1}{L}\left(V_{in} - \frac{V\ \ f2}{2}\right) = \frac{1}{L}\left(V_{in} - \frac{V\ \ f}{2}\right) \quad (9)$$

Where Vcf = Vcf1 = Vcf2.

The topology in Fig.5(c) is identical to topology shown in Fig.5(a). During this, again both S1 and S2 are ON and Il1 and Il2 start increasing as given by equation (5). At the same period both the output filter capacitors Cf1 and Cf2 starts discharging through the load.

The converter then enters into the final topological cycle shown in Fig.5 (d), when S1 turns OFF and current through L1 commutated through D1. At this time the energy stored in L1 and L2 through previous cycles will get discharged into capacitor Cf1. So Vcf1 increases and Vcf2 continues to fall off. The cycle repeats when S1 gets ON again.

The voltage conversion ratio of the circuit is calculated from the output – time balance of the boost inductors. From the Figs.(5) and Fig.(6), the Volt-Second balance is given by the equation for L1 is

$$V_{in}\,D\frac{}{2} = \left(\frac{V\ \ f}{2} - Vin\right).\left(\frac{}{2} - D\frac{}{2}\right) \quad (10)$$

So that,

$$\frac{V}{V} = \frac{4}{1-} \quad (11)$$

Since Vo = 2Vcf. As it is seen from the above Eq.(11), the output voltage of the converter shown in Fig.(3) is by 4 times as that of the input. This high gain makes this converter suitable for Solar PV applications.

It is also noted that due to the unique property of the converter, simultaneous charge and discharge of Inductors and Capacitors which is achieved through the Auxiliary transformer helps to maintain a good regulation through variety of loads. With the Duty cycle unity, the maximum power transfer occurs. With L = L1 = L2 and Unity transfer ration of the auxiliary transformer, the output jumps to four folds.

According to the equation (11), the above statement holds true and the switches S1 and S2 must be operated in complement to each other. Since the auxiliary transformer has unity turn ratio, the output capacitor is charged with twice the voltage and with voltage doubler action the output becomes four fold.

Fig.7 (a) and Fig.7 (b) illustrate the applications of the same Two Inductor Boost Converter with full wave topology and with isolation and with integrated magnetics respectively.

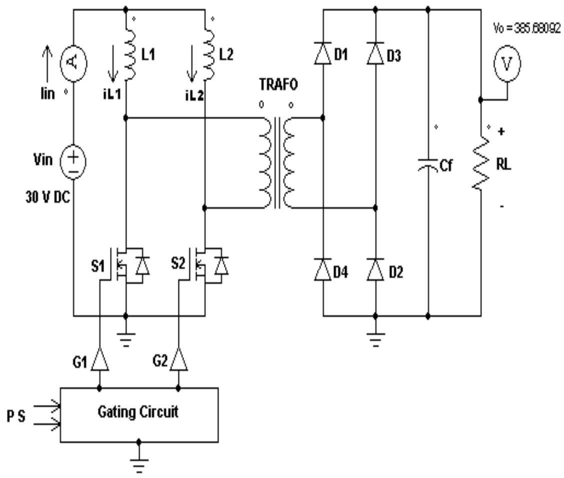

Fig.8(a) Implementation with Isolation Transformer

Fig.7 (a) has four diodes and separate filter capacitor. This has a very good voltage regulation but has lesser voltage gain.

Fig.7 (b) is a non-isolated version in which the auxiliary transformer and boost inductor can be integrated into a single magnetic core with proper end connections. For example the integration can be achieved by selecting or redesigning proper value of inductances so that the leakage inductance helps the boost action. This is cost effective and space saving design.

3. EXPERIMENTAL RESULTS – BY SIMULATION.

A. Technical Specifications.

To construct a schematic shown in Fig.(8) and to verify the results for regulation and the efficiency through PSIM simulation software.

- The input voltage Vin = 30 to 60 Vdc from Solar PV.
- Output voltage Vo = 380 Vdc (controlled).
- Power output Po = 300 Watts.
- Switching frequency = 20 KHz.
- Expected efficiency ≥ 90%.
- Battery backup = optional.

B. Components selection.

The Table.(1) shows the component values for simulation and for hardware assembly as well.

Table : 1 Components list

Sl.No	Name	Type	Remark
1	Solar PV Module	Titan M6-60 250 Watts	2 nos
2	EMI Module	20A, 500 V DC	1 no
3	Auxiliary Transformer	ER28L or equivalent	1 no
4	Boost Inductors	77071-A7 or equivalent	2 nos
5	IGBTs	IRFP264	4 nos
6.a 6.b	Diodes	RHRP1560 BYM26C	2 nos 2 nos
7.a 7.b	Capacitors	25uF / 250 V DC 680uf / 250 V DC	1 no 2 nos

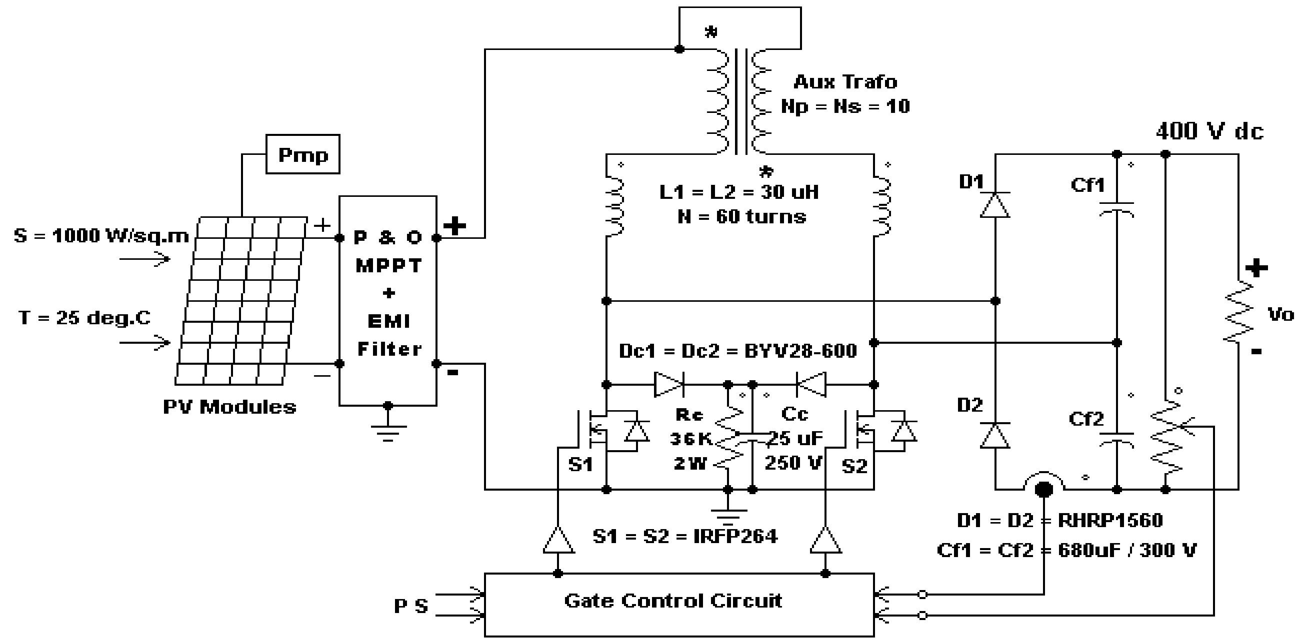

Fig.9. Schematic diagram of 300 Watts TIBC

The performance of the discussed TIBC is verified with PSIM Version.9.0.3 and the resulted key waveforms are put in Fig.(6). By adding a P&O MPPT charge controller, the TIBC is suitable for solar PV applications. For example a small garden pump or a small domestic pump can be run directly from the circuit by selecting a suitable inverter.

The simulation is carried out for various combinations of input DC voltage and load. The most sensible load is produced here to make it simple.

4. CONCLUSION.

The proposed Two Inductor Boost Converter is fed with Solar PV modules through P&O MPPT charge controller. The DC output is tuned to match the Inverter DC link voltage of 380 to 400V DC so that the output is 220 V AC, 50 Hz and a small water pump of 250 watts can be run. The closed loop control with DC link voltage feedback is simulated to maintain 380 V DC constant at DC link. The PWM is a constant frequency and variable Duty ration one. The described Two Inductor Booster topologies with the auxiliary transformer are well suitable for high voltage gain (4 to 6 times of the input) and wide range of loads. The simulation gave satisfactory results in terms of regulation of voltage and conversion efficiency. The battery source is left as a optional component. Also several such boosters can be connected in cascade to achieve very high power as it may be needed.

REFERENCES

[1] Yungtaek Jang and Milan M Jovanovic -2002 IEEE New Two-inductor Boost Converter with and without Auxiliary Transformer. 0-7803-7405-3/02/2002 IEEE.

[2] Joao Victor and Luis Felipe – Implementation of a High efficiency And low cost converter for a Photovoltaic water pumping system. 978-1-4577-1216-6/12 2012 IEEE.

[3] P.J.Wolfs, “A Current –sourced dc-dc converter derived via duality principle from half bridge converter,” IEEE transaction on industrial electronics, VOl. 40 , PP.139-144,1993.

[4] G.Ivensky, I.Elkin, S.Ben-Yakov, “An isolated DC-DC converter using two Zero Current switched IGBT,s in a symmetrical Topology, “ IEEE Power Electronics Specialists’ conference.Rec., PP. 1218-1225,1994.

[5] W.C.P. de Arago Filho, I.Barbi, “A Comparison between two current –fed push–pull dc-dc converters-Analiysis, design and experimentation,” IEEE international Telecommunication Energy conf. proc,Rec., PP.313-320,1996.

[6] Gnanavadivel and Malathi – Power Electronics – Anuradha Publications. 2003. ISBN 978-81-8472-138-6.

Acknowledgement

I wish to acknowledge here to my Guide Dr.I.Gnanambal for the valuable suggestions, the Authors Mr Yungtaek Jang and Mr Milan M Jovanovic for their inputs and other reference material Authors.