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Design and Simulation of Efficient DC-DC Converter Topology for a Solar PV Modular Integrated Converter System

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Abstract: Modulated Integrated Converter systems are considered to be the new and global turning point in the field of Solar PV systems. These converters are highly recognised for its modular size and compact nature and they are supposed to be attached directly with each PV module and since one PV module is having the power rating of a few watts ranging from 0-500Ws, the design rating would be in the same range and thus the most vital condition in such a design is efficiency under these relatively low loads. In this paper an isolated interleaved boost converter topology is considered in the DC-DC section and which is designed and simulated for a specific power rating (250W) and the efficiency is analysed with varying load conditions and compared with the target efficiency of the system.

Keywords: Interleaved Isolated Boost Converter, Modular Integrated Converters (MIC), DC-DC Converters, MPPT

I. INTRODUCTION

In the present scenario of power crisis, renewable energy gains its importance and solar energy is the best energy solution considering the weather conditions but, it is blamed to be uneconomical compared to the conventional energy, due to the high cost of installation and maintenance. While exploring the causes of high cost, the inflexibility of power generation is found to be the major problem. Generally, rooftop solar photo voltaic (SPV) generation systems are designed and installed for particular output powers irrespective of the requirement of the local load where the SPV system is installed and they are not grid interactive. In this aspect grid connection is considered to be a solution. Also, in-order to maximize the harvesting of solar power, building integrated solar PV systems (BIPV) can be considered. String connected converter and inverter systems are in use now, which decreases the reliability due to the fact that if any one device in a string fails, the whole system fails. Apart from that the shading effect on cells could create multiple maxima's in the operating characteristics of the cell hence harvesting the maximum energy would be difficult ask. A grid interactive modular integrated converter (MIC) can act as a solution to most of these problems.

In a MIC system, each module will be equipped with its own converter and inverter systems so that it can act as a plug in power generator. The system consists of a DC-DC conversion section and a DC-AC conversion section. This system reduces the effect of failure and since it is in modular form no cooling accessories are required. However it couldn't be realised in the mainstream market due to some problems in the initial designs. The main problem with earlier designs and their limited success was due to the poor efficiency, lack of reliability and the price factor. This paper focuses on this major issue of efficiency in the system and a detailed analysis is conducted in one of the major parts of modular integrated converter (MIC) system, ie the DC-DC converter which is entitled to give a stable DC bus voltage irrespective of the PV supply functions due to irradiation and temperature changes through MPPT (Maximum Power Point Tracking).

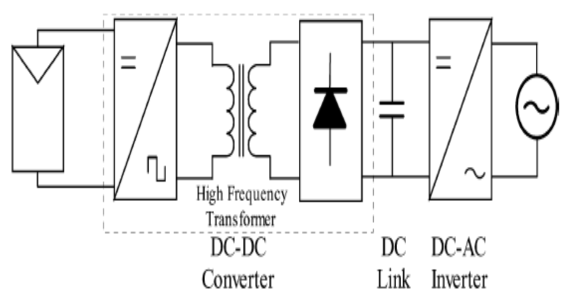

Fig. 1. MIC System with DC link

As shown in the figure there are two parts in a MIC system a DC-DC side and DC-AC side to convert to AC grid voltage. This paper focuses on the phase one of this circuitry and the MIC topology considered here is with DC link. There are other topologies such as MIC without DC link and with a pseudo DC link can also be considered. A 250W rated MIC system is designed with interleaved isolated boost converter with a high frequency transformer as DC-DC converter topology and the efficiency of the system is calculated under various load conditions.

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II. DC-DC CONVERTER

The DC-DC conversion section requires high efficiency and high voltage step up capability. From a standard PV panel, the available input will be in the range of 20-40 volts. An interleaved boost converter will serve as the dc-dc converter and which will give a gain of 2. After this part, we can either use capacitor voltage doublers or transformers. Since galvanic isolation is required for this circuit, transformer is included. A high frequency (HF) transformer is used in-order to reduce the size. Due to the use of this HF transformer, the switching frequency (f_s) of the converter has to be kept high. But for a transformer, leakage flux has to be minimum. Leakage flux depends on the windings and hence on the turns ratio. Therefore, in-order to keep the leakage flux of the transformer to minimum, its turn's ratio is maintained within limits. This is made possible with the use of capacitor voltage doubler in conjunction with the HF transformer.

Interleaved technology helps in increasing the efficiency by cancelling the input current ripple. And also due to the division of current by exactly half, the power ratings of the devices in each path can be made exactly half compared to a single level converter. The dc voltage from the PV panel is the input voltage of the converter. Circuit diagram of the interleaved boost topology used in the DC-DC conversion section is given in the Fig. 1.

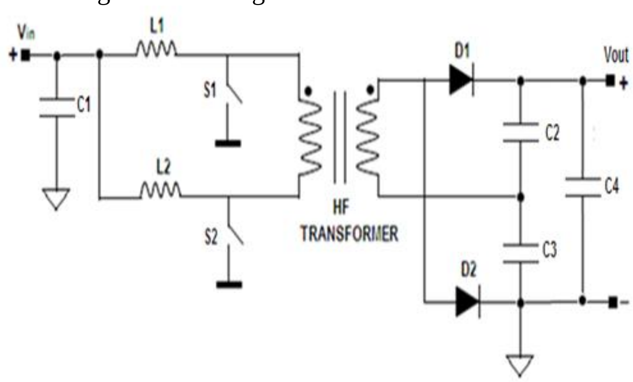

Fig. 2. Interleaved Isolated Boost Converter

The converter operates in continuous conduction mode. It has 4 operating intervals. During the first interval, switch S1 is ON and S2 is off, the inductor L1 charges and its current increases linearly with a slope proportional to the dc input voltage. The inductor L2 discharges and the current passes through the primary of the transformer, the voltage will get stepped up and the voltage doubler steps up the voltage further. During the second interval, both the switches are ON and the inductors L1 and L2 charges. During this interval the capacitor meets the load. During the third interval, S2 turns ON and S1 turns OFF. L2 charges and builds current linearly while L1 discharges with a slope proportional to the difference between the input and output voltages. During the fourth interval, both switches turn ON, L1 and L2 charges and the output capacitor meets the load. The switching pulses are given with a phase difference of 180 degrees and the duty cycle will be greater than 50 % as shown in Fig.2.

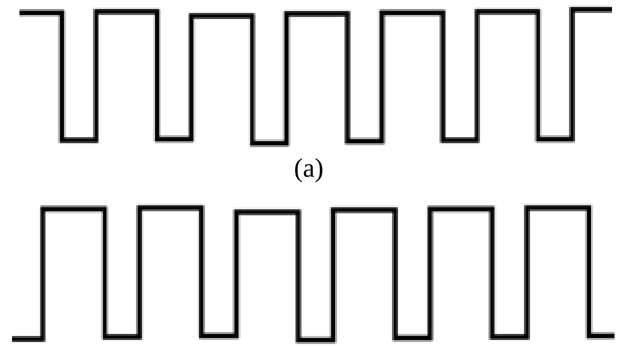

Fig. 3 Gate pulses for the switches (a) S1 and (b) S2.

III. PARAMETER SPECIFICATIONS AND DESIGN

The interleaved boost converter is designed for an output power of 250W.Since the output power is channelled through two paths; the components of the power path are designed for half the rated power.

TABLE I
DESIGN SPECIFICATIONS

V_{inmin}	20V
V_{inmax}	40V
P_o	250W
η	97%
f_s	35kHz

Knowing maximum input voltage (V_{inmax}, V_{inmin}, $V_{outrate}$) and the voltage drop across output diodes and switches, the maximum and minimum duty cycle (D) can be calculated. Average inductor current can then be calculated from the load current and the duty cycle. The peak inductor current can be estimated by assuming the peak current a certain percentage of the average inductor current. Inductor current can then be calculated by using the values of ripple current, switching frequency (f_s), D and input voltage.

A. Duty cycle.

The switch duty cycle will always be greater than 0.5.
Switching period,

$$T = \frac{1}{f_s} \quad (1)$$

Let D be the time beyond the half period for which the switch is still closed.

$$D_{max} = \frac{tonmax}{T_s} - 0.5 \quad (2)$$

B. Transformer Turns Ratio.

$$\frac{N_2}{N_1} = \frac{\frac{V_{out}}{2}}{2V_{in}}(1 - D) \quad (3)$$

C. Input Inductor.

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$$P_{lim} \approx 10\% \, P_{out} \quad (4)$$

$$I_{lim} = \frac{P_{lim}}{2\,Vin} \quad (5)$$

$$\Delta I_{lim} = I_{lim} \quad (6)$$

$$L = \frac{V_{inmin} \; D_{switc\,hmax}}{\Delta I_{ind} \, f_s} \quad (7)$$

D. Input Capacitor.

$$C_{in} = \frac{\Delta i_c}{\Delta v_c . f_s} \quad (8)$$

Where Δi_c is the capacitor current ripple and Δv_c . is the capacitor voltage ripple.

E. Calculation of Output Capacitor.

$$C = \frac{D.T_s \, I_o}{\Delta V_{max}} = 1.92\mu F \quad (9)$$

IV. SIMULATION AND ANALYSIS

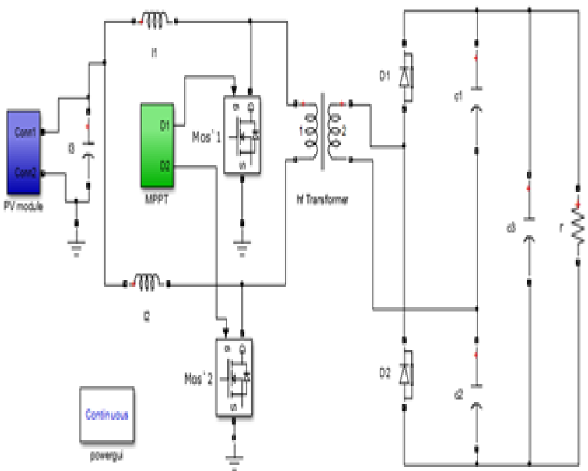

Fig. 4 Matlab-Simulink diagram of DC-DC converter.

As shown in the figure 4, designed circuit is simulated in the matlab Simulink. A Solar PV module is mathematically modelled and connected at the DC input of the DC –DC converter under standard test condition of 1000W/sq.m and with a temperature of 25K. In order to switch the converters two complementary pulses were generated at a switching frequency of 35 kHz and in order to track the maximum power point using Pertube and Observe (P&O) algorithm is also implemented in the simulation and which will vary the duty cycle according to the Vmpp & Impp (Maximum power point V and I values of the PV cell).The switching pulses thus generated are as shown in the figure 5.

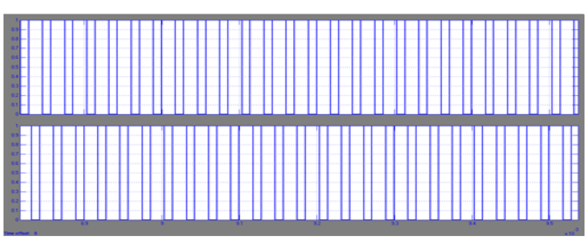

Fig. 5.Complementary gate pulses at Switching Frequency(*fs*=35KHz).

The main objective of an MIC design is to maintain the dc bus voltage constant under varying irradiation and temperature condition. By the specific design of this circuit a nominal dc voltage of 380V is maintained as shown in the figure 6.And the nature of transformer current is shown

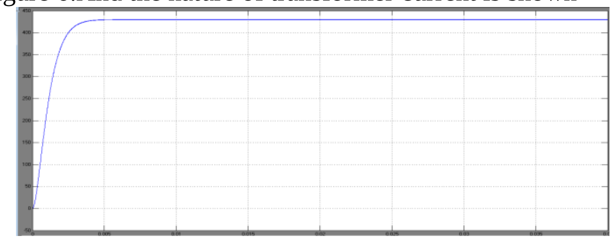

Fig. 6.DC Bus Voltage.

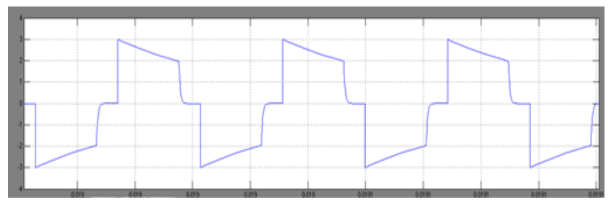

Fig. 7. High Frequency Transformer Current.

Since the main target of the project is to recognise the efficiency of the system under varying load condition, the system is simulated with DC load varying from 50W to 250W,the full load. The input and output power is measured with varying load conditions as specified above and a graph is plotted between efficiency and output power as shown in fig 8.Under the lowest load condition of 50W an efficiency of 94.3% is achieved and it has rised as the load was gradually increasing and reaches to the design target efficiency of 97%.Since the switching frequency is maintained as high as 35kHz, under this light load condition constant losses are minimised to a greater extent.

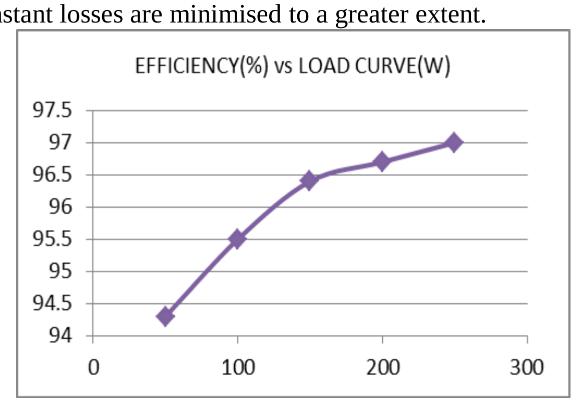

Fig. 8 Efficiency Curve of DC-DC Converter

V. CONCLUSION

It is evident that with the MIC solar generation system, higher productivity and greater reliability can be achievd.For the due purpose Interleaved Isolated Boost converter topology is designed for DC-DC section and simulated for a rating of 250W and it has been observed that the efficiency of the system is as high as to be used for commercialization thus it can be concluded that the topology under consideration is an apt one for MIC systems.

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REFERENCES

[1] Wuhua Li and Xiangning He,, "A Family of Isolated Interleaved Boost and Buck Converters With Winding-Cross-Coupled Inductors," IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 23, NO. 6, NOVEMBER 2008

[2] Quan Li, Member, IEEE, and Peter Wolfs, Senior Member, IEEE,, "A Review of the Single Phase Photovoltaic ModuleIntegrated Converter Topologies With Three Different DC Link Configurations," IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 23, NO. 3, MAY 2008

[3] Sonal Panwara, Dr. R.P. Sainib, "Development and Simulation of Solar Photovoltaic model using Matlab/simulink and its parameter extraction," International Conference on Computing and Control Engineering (ICCCE 2012), 12 & 13 April, 2012.

[4] P. D. Maycock, "World PV cell/module production," PV News, vol. 25,no. 3, Mar. 2006./

[5] G. R. Walker and J. C. Pierce, "Photovoltaic dc–dc module integrated converter for novel cascaded and bypass grid connection topologies—Design and optimisation," in Proc. IEEE PESC, 2006, pp.3094–3100..

[6] C. Liu, B. Wu and R. Cheung, "Advanced Algorithm For Mppt Control of Photovoltaic System" Canadian Solar Buildings Conference Montreal, August 20-24, 2004

[7] David Sanz Morales," Maximum Power Point Tracking Algorithms for Photovoltaic Applications", Thesis submitted for examination for the degree of Master of Science in Technology. Espoo 14.12.2010

BIOGRAPHIES

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