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Improving Efficiency of Solar PV Module Using Interleaved Boost Converter

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***Abstract*: The changing climate is a great challenge to many nations, making them to move toward setting renewable energy targets. Some energy sources are inexhaustible; they do not emit any kind of dirty greenhouse gases or any toxic waste in the process of producing electrical energy, and they are known as renewable energy sources. In a country like India, where the demand to increase the power generation capacity is rising as the consumption is increasing, here the best option is to adopt renewable energy sources. India is a country with abundant sunlight; it is situated at a best geographical location with almost 300 sunny days [5]. Here the solar power generation tops the list, but the solar PV efficiency is low and its output always depends on solar insulation level. So in order to increase the output of these sources we need suitable boost converters, one such boost converter is an interleaved boost converter which employs interleaving technique, and this proposed method provides increased output voltage along with better efficiency. Here, we are going to form a two phase interleaved boost converter consisting several identical components connected in parallel forming stages between source and load. These components are operated at same frequency and phase shifts, reducing all current ripples and giving a smooth output at load side. [6] The results are verified by theoretical methods, and simulation is done through MATLAB.**

***Keywords*: Solar energy, Interleaving technique, Current sharing, Continuous conduction mode, BLDC motor.**

1. Introduction

Energy is an important input in all the sectors of any country's economy. Of course, as we all are aware, we are in a rapidly evolving country and in a changing environment bringing new challenges each day making us switch from non-renewable energy sources to renewable energy sources which are also called as 'natural', 'alternative', 'new', sources.

Energy needs of developing country like India are increased significantly, which produces more attraction for many people towards renewable energy sources. Any such renewable energy system requires a suitable converter to make it efficient; example a solar PV generation system which has quite low output voltage here a boost converter can help converting low input voltage into high voltage outputs. But in the case of conventional boost converter, the converter current injected into load is discontinuous and capacitor current has high ripple content at output, with low voltage gain. Here, replacement of conventional boost convertor by an interleaved boost converter can be very advantageous improving the output voltage with better efficiency up to 98%, faster dynamic, high power density, low current ripple. Interleaving technique is connecting two or more boost converters in parallel with common load and capacitor, wherever there is high power requirements in order to meet them connecting interleaved channel converters can cause reduced voltage stress, also the inductor current get reduced by half, as a result total loss of inductor significantly gets reduced, effective ripple frequency increases by twice, also inductor capacitor filter size gets reduced improving efficiency of system.

2. IBC Circuit Configuration

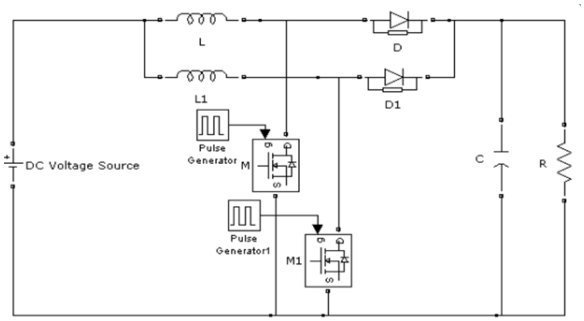

Fig. 1. Circuit diagram of interleaved boost converter [1]

Interleaved boost converter basically consists of several identical boost converters connected in parallel with same switching frequency and phase shift, as here we are using only two stage of power converter in parallel, hence only 2 inductors, 2 MOSFETS as switches, and 2 diodes, connected to common load and capacitor have been used. Here it consists inductor L1 in parallel with inductor L2, switch Q1 in parallel with switch Q2, diode D1 in parallel with diode D2, which acts as 2 channels between the 2 paths i.e. between input and output sides. Now, for obtaining interleaving operation or multi-phasing or multi-channel operation all identical components are been used. Two switches use are MOSFETS, which are

operated at same frequency but at phase difference of180° also this can be said as two MOSFETS are provided gate signal which is out of phase 180°. As, the output current is divided into number of stages the current stress gets reduced. MOSFETS have very high efficiency at low voltage and a good commutation capacity.

Duty ratio plays very important role here; the output of the given input voltage depends upon the duty ratio. The ripple content reduces with the increase in the number of phases; 3 phases can also be a good consideration, but as increasing the number of phases can cause bulkiness of circuit and also the cost increases so we are forming the circuit with only two phases. [2]-[4].

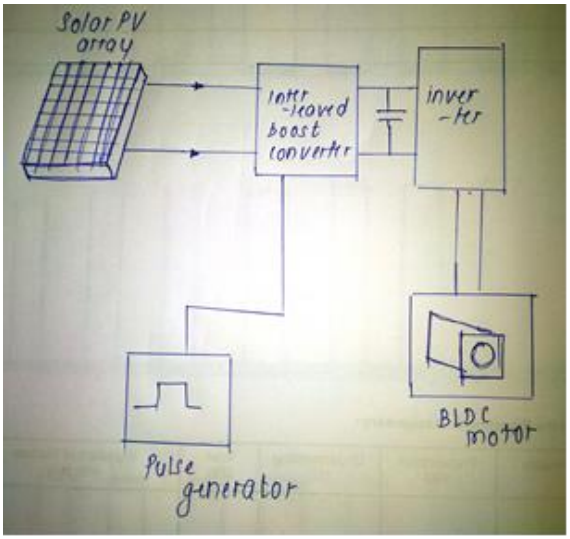

Fig. 2. BLDC motor connected to interleaved boost converter fed by a solar PV array

3. Operation of IBC

Interleaving technique is also called as multi-phasing, a technique consisting various power converter into parallel connection. All identical components have been used in parallel paths between the input and output.

Here the switches used are MOSFETs, because of its high commutation speed and high efficiency at low voltage, each MOSFET is switched at same frequency, but at a phase difference of 180°, because every phase shift is given as $\frac{(360°)}{(N)}$; where N stands for number of phases and as we are using only two phases the phase difference is 180° , hence it proved that phase shift depends of number of phases.

When at first gate signal is given to the MOSFET M1, the current across the inductor L1 rises linearly and energy gets stored into the inductor L1. When the MOSFET m1 is turned OFF, the diode D1 transfers the stored energy form the inductor L1 to the load. The inductor and capacitor serve as voltage sources to improve the voltage and to reduce the voltage across each MOSFET. The increasing current rate across the diodes is controlled by inductor into phase. Now the gate signal or pulse is given to the MOSFET M2, same way current across inductor L2 rises, storing energy into it. When M2 is turned OFF, the diode D2 transfer the stored energy from inductor L2 to the load. In this way, the circuit works in continuous conduction mode in which inductor current remains positive at all time. The two phases operate at 180° out of phase, cancelling ripple current in the output of capacitors.

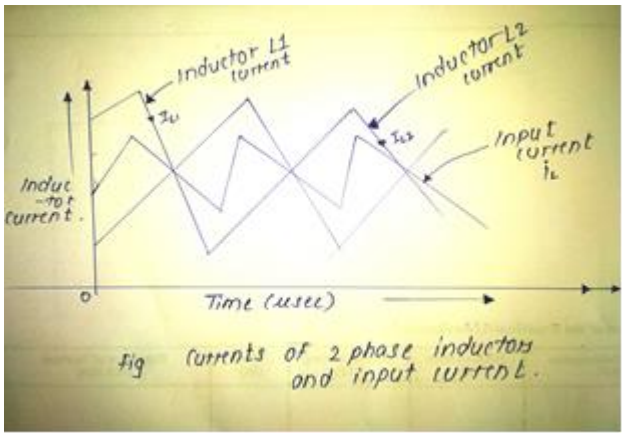

Fig. 3. Currents of 2 inductors at the 2phases, in variation to input current

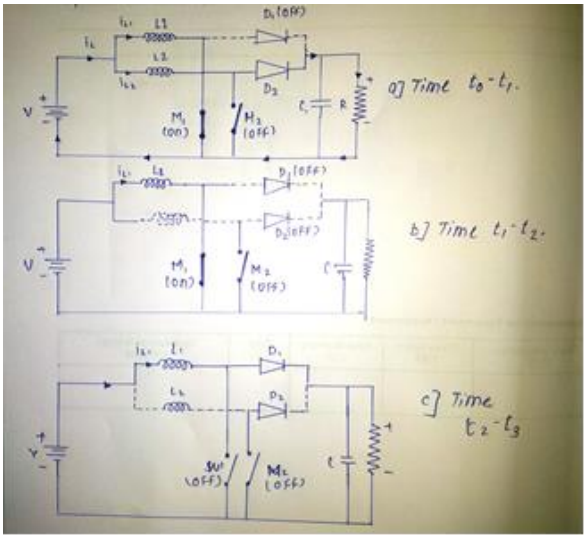

Fig. 4. Operation of various components at different time intervals

Fig. 4 represents the operation of various components at different time intervals. At time t_0, M_1 is closed. The current in the inductor L_1 starts to rise while L_2 continues to discharge, at time t_1, L_2 falls to 0, L_1 continues to rise and at time t_2, M_1 is opened. The energy stored in the inductor L_1 is transferred to the load through the diode D_1. The MOSFET M_2 is closed at time t3, the current in inductor L_2 starts to rise, L_1 continues to discharge. At time t4-t5, the inductor current of L_2 rises, M_2 is opened. L_2 discharges through the output circuit. [3], [4]

4. Design of IBC

This involves proper selection of;

1) Selection of inductor and capacitor values

In IBC inductor is used to transfer energy from input voltage to inductor current and to convert it back from inductor current to output voltage, hence both inductor used in the circuit are of same values, which will help sharing input current equally, also inductor peak current rating is reduced.

Formula used to find value of inductor given is:

$$L = \frac{v_{in} * d * Ts}{2\Delta I_0}$$

Where:

Ts is switching time, ΔI_0 output ripple

The value of capacitor:

$$C = \frac{DV_0}{R\Delta V_0 f_s}$$

2) Duty cycle

$$\frac{V_0}{V_{in}} = \frac{1}{1-D}$$

Where; D is duty ratio

3) Input current can be calculated by input voltage and input power

$$I = \frac{P_{in}}{V_{in}}$$

4) Inductor current ripple peak-peak amplitude

$$\Delta I_{l2,l2} = \frac{V_{in}\, D}{f_s\, L}$$

Where; V_{in} represents the input voltage, f_s represents Switching frequency.

5) Solar PV module

We have selected solar PV array of 1620W. The power capacity of solar PV array is little more then what of the motor selected, as there may be some kind of losses which may affect the efficiency of motor, and converter. The solar panel selected is connected in series-parallel form, to give the required voltage.

No. of cells	36
S.C current	6.4A
O.C voltage	21V
V_m	17V
I_m	5.4A
Number of modules in series	4
Number of modules in parallel	2
Voltage Vmpp	153V
Power	1620W

6) BLDC motor

A BLDC motor is the one which consist of fixed armature and permanent magnet rotating around it, which eliminates problem of connecting current to armature associated with it. They are usually called as electronically commutated motor. This motor is powered by integrated inverter, which produces AC signal to drive the motor. Stator windings are connected to a control circuit, it energizes proper winding at proper time, in a pattern which rotates stator. The rotor magnet tries to align with the energized electromagnet of the stator, and as soon as it aligns, the next electromagnet is energized and this process will continue. This will make the rotor to run continuously [3].

Power	1.32kW
Speed	3000rpm
DC voltage	310V
No. of poles	4
Current	4.3A
Torque constant	0.74Nm/A
Inductance/phase	9.13mH
Resistance/phase	3.58ohm

Advantages of BLDC:

1) High Reliability as BLDC motors do not have brushes, making more reliable and have life expectancies, of up to 9000 hours.
2) BLDC motor always have high speed of operation up to 10,000rpm.
3) As compared to other dc motor it has high torque per cubic inch.

5. Block Diagram

The solar panel located absorbs the light, and gives the output to the interleaved boost converter, which reduces current ripple and boost up the output voltage. The interleaved boost converter consists of two MOSFETS, and a connection of control circuit which is a three phase inverter consisting 6 switches of the BLDC motor connected. The signal comes through the driver circuit which is intern operated by arduino microcontroller. The control circuit energizes proper winding at proper time, then the feedback from motor is achieved by hall sensor connected to Arduino.

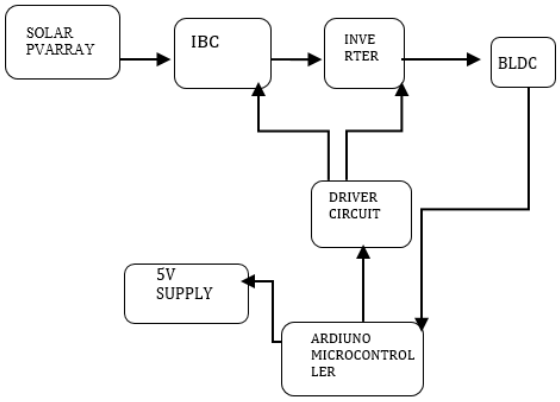

Fig. 5. Block diagram

The sensor carry principle, that whenever a current carrying conductor is exposed to magnetic field, the charge carrier experience force based on voltage across the 2 sides. If the

direction of magnetic field is reversed the voltage develop will also get reversed. Whenever magnetic poles, comes across the sensor, it generates high or low signals, used to sense position of shaft. Then the microcontroller will control driver circuit, intern controlling the BLDC motor.

6. Advantages of IBC

1) Its an Environmental friendly experiment.
2) Using two phase IBC, can reduce cost of complexity.
3) Two phase IBC uses all the input from the solar panel to make it efficient.
4) As compared to other conventional boost converter, interleaved boost converter is very compact, has good voltage capacity, and more efficient.
5) Has low input current ripple at capacitor.
6) Low voltage steady state ripples.

7. Conclusion

Selection of interleaved boost converter plays an important role in efficient utilization of energy from a solar PV array. Through load voltage and load current waveform simulation, it's concluded that the power factor of circuit is near to unity; hence it can be used where power factor correction is needed. When we observe the inductor currents we can clearly find that with same frequency and duty cycle the ripple is reduced. Duty cycle also plays an important role, because the desired output voltage for given input voltage always depends on duty cycle. Instead of always connecting power devices into parallel, connecting power converter can be more beneficial. Two phase interleaved boost converter reduces output current RMS, because of this the capacitor of small rating and size can be selected. Also a reduced input current and voltage ripple at capacitor makes it more superior [7].

Therefore, an interleaved boost converter is a best choice for boosting the efficiency of a renewable energy based solar PV array.

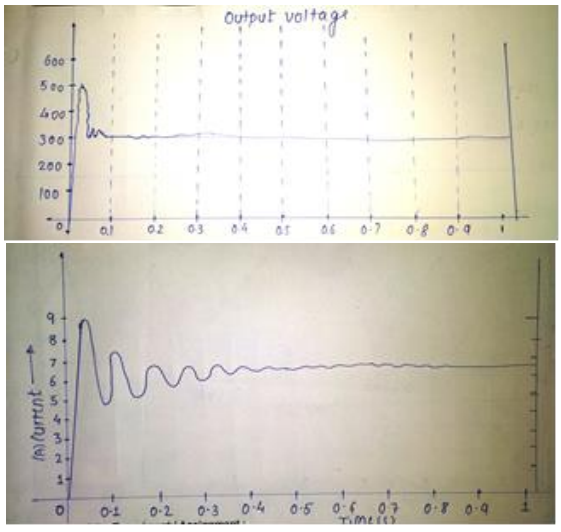

Fig. 6. No ripple at the output voltage and current of capacitor

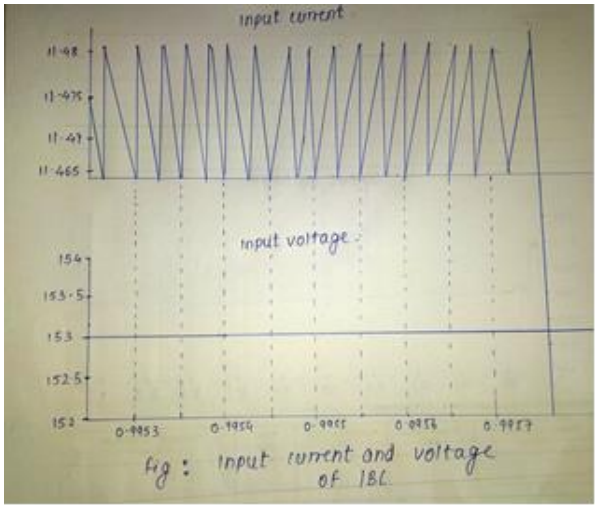

Fig. 7. Input voltage and current at the IBC, where we can see there are no ripples

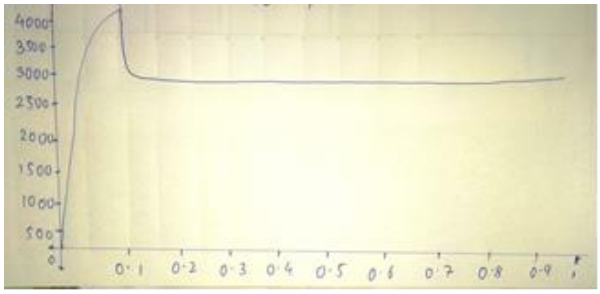

Fig. 8. Rotor speed of BLDC motor

The input voltage Vpv = 153 V, the rated input voltage of BLDC motor is 310 V and rated speed of 3000 RPM at full load.

References

[1] Chitra P and Seyezhai R, "Basic design and review of two phase and three phase interleaved boost converter for renewable energy sources," International journal of applied science.
[2] Daniel Hart, Power Electronics, Tata McGraw Hill Edition 2011, New York.
[3] Pradeepakumara V, Nagabhushan Patil "Renewable Energy source based interleaved boost converter", IJISET, Vol. 3, Issue 8, August 2016.
[4] K. Latha Shenoy, C. Gurudas Nayak, Rajashekar P. Mandi, "Design and implementation of interleaved boost converter", International Journal of Engineering and Technology.
[5] G. D. Rai, "Non-conventional energy sources", Khanna publication.
[6] Ajit NT, "Two Stage Interleaved Boost Converter Design and Simulation in CCM and DCM", International Journal of Engineering Research & Technology, Vol. 3 Issue 7, July 2014.
[7] Rohit D. Tayade & Shrikant s. mopari," Comparitive analysis of interleaved boost converter and cuk converter for solar power bldc motor", International Journal of Electrical and Electronics Engineering, Vol. 6, Issue 4, Jun - Jul 2017, 1-12