Non-Isolated High Step-Up DC-DC Converter for Renewable Energy Sources

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Abstract— This paper proposes that, the input voltages in DC-DC converters are step-up without using a transformer. The drawbacks of a conventional boost converter are, at high duty cycles it cannot have any control over input current, it draws considerable amount of current from the source which can create problems for other components and the voltage stress across the switch comes nearly equal to output voltage with electrical parameters such as voltage gain, power loss and switch voltage stress. These problems can be overcome in the proposed topology discussed in the paper. The comparison is performed between conventional boost converter and boost converter with improved topology. The proposed converter design and its implementation are given with operational results and the results are tested for an input voltage of 12V. The proposed topology is presented by taking the input from the renewable energy source like PV-panel. The topology was implemented in MATLAB/ SIMULINK environment.

Key words: Renewable Energy Sources, Non-Isolated High Step-Up DC-DC Converter

I. INTRODUCTION

Renewable energy is the energy which comes from natural resources such as sunlight, wind, rain, tides and geothermal heat. These resources are renewable and can be naturally replenished. Therefore, for all practical purposes, these resources can be considered to be inexhaustible, unlike dwindling conventional fossil fuels. The global energy crunch has provided a renewed impetus to the growth and development of Clean and Renewable Energy sources.

Solar energy can be utilized in two major ways. Firstly, the captured heat can be used as solar thermal energy, with applications in space heating. Another alternative is the conversion of incident solar radiation to electrical energy, which is the most usable form of energy. This can be achieved with the help of solar photovoltaic cells or with concentrating solar power plants.

A photovoltaic cell or photoelectric cell is a semiconductor device that converts light to electrical energy by photovoltaic effect. If the energy of photon of light is greater than the band gap then the electron is emitted and the flow of electrons creates current.

MPPT (Maximum Power Point Tracking) is a technique to charge the controllers and that charge is used to improve or to increase or maximizes the output power for wind turbines and PV solar systems.

PV solar system exist several configurations. The most basic version sends power from collector panel directly to DC-AC inverter and from there directly to the electrical grid. The second version called a hybrid inverter, in which some percentage of power goes to the grid and remaining goes to the battery bank. The third version is not connected to the grid but it acts as PV inverter that features the mppt. Here power flows directly to the battery bank. The variation of these configurations is, instead of single inverter a micro inverter is used for each PV panel which increases the efficiency up to 20%.

The following are the types of mppt techniques

1) Perturb and observe method
2) Incremental conductance method
3) Fractional open circuit voltage
4) Fractional short circuit current
5) Fuzzy logic control
6) Neural network

A. *Perturb and Observe Method:*

It is the simplest method, the cost of implementation is less and easy to implement. Here we use only one sensor (voltage sensor) to sense the PV array voltage. Time complexity is very less but on reaching very close to mppt it doesn't stop at the mppt and keeps on perturbing on both the directions. When this happens the algorithm has come very close to the mppt and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of algorithm. The main drawback of perturb and observe method is, it doesn't consider the rapid change of irradiation level due to which mppt changes.

B. *Incremental Conductance Method:*

Here we are use two voltage and current sensors to sense the output voltage and current of PV array simultaneously. Hence the error due to change in irradiations can be eliminated which increases the cost and complexity.

C. *Fractional Open Circuit Voltage:*

D. *Fractional Short Circuit Current:*

E. *Fuzzy Logic Control:*

The advantages of this method is working with imprecise inputs, not needing an accurate mathematical model and handling non linearity. Microcontrollers have made using fuzzy logic control.

F. *Neural Network:*

It has three layers. They are input, hidden and output. The number of nodes in each layer is user dependent. The input variables may be PV array parameters (open circuit voltage and short circuit current), atmospheric data (irradiance, temperature and any combination of irradiance and temperature). The output parameters are duty cycle signal (used to drive the power converter to operate or close to the mppt).

Boost converters are the converters with the dc output voltage greater than its input dc voltage. It is a class of switching mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element. Filters made of capacitors are normally added to the output of the converters to reduce the output of the ripple. This converter has the advantage of simplicity and high efficiency. This converter is transformer-less and thus has the desirable features of high efficiency, low cost and small size. Boost converters do not require isolation which is used in many applications. For example, DC back energy systems for UPS, fuel cell systems, renewable energy systems etc. to use boost converters it has the requirements of high step up voltage gain, high current handling capability, high efficiency of a desired level of volume and weight and low input current ripple.

To improve high output voltage, the boost converter should operate at extremely duty cycle and then diode must sustain a short pulse current with high amplitude. By using extreme duty cycle may also lead to poor dynamic responses to line and load variations as well as results in serious reverse recovery problem. The basic boost converter is a simple boost structure with a high step up voltage gain, but the active switch of this converter will suffer a high voltage stress. The input current is large in the boost converter and hence low voltage rated MOSFET's with small Rds (ON) are necessary in order to reduce the dominating conduction loss. The switch in the boost converter should sustain high output voltage as well and therefore the device selection is faced with a contradiction. High step up boost converter topology have been presented to overcome the problem.

Basically boost converter is a power converter with an output dc voltage greater than its input dc voltage.

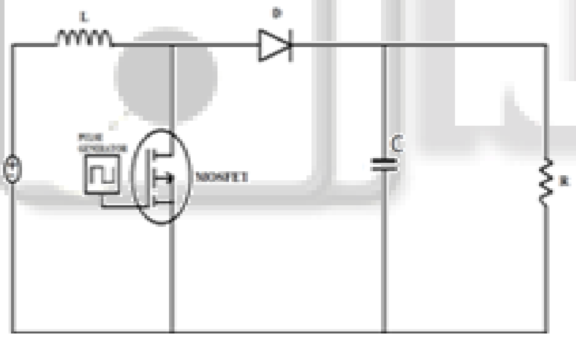

Fig 1: Simple Boost Converter

The operation of the boost converter is to boost up a certain input voltage to a higher level at the same time the boost converter steps down the current as a natural result of the energy conservation principle which implies that power being the product of voltage and current must be conserved. The boost converter is based on the tendency of an inductor to resist changes in its current. When an inductor is charged, it behaves like a load as it absorbs energy. On the other hand, when it discharged, it behaves as an energy source. The operation of the boost converter is explained when the switch is closed, the inductor is charged its current increases. When the switch is open, the only path offered to inductor current is through the diode D, the capacitor C and the load R. it indicates that energy generated during the ON state is transferred in to the capacitor.

The operation of boost converter is explained below.

It includes two distinct stages

- On state: In which the switch is closed, and thus the inductor is charged, i.e. , its current increases (Fig 2).
- Off state: The switch is open and the only path offered to inductor current is through the diode D, the capacitor C and the load R. This result in transferring the energy accumulated in to the capacitor during the on state (Fig 3).

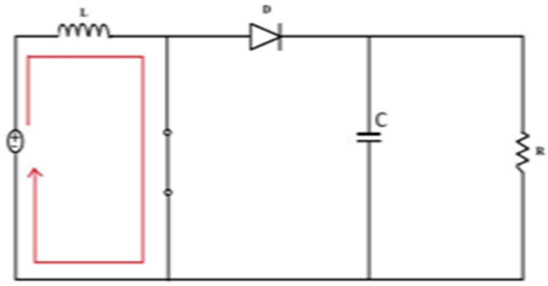

Fig 2: Switch is on

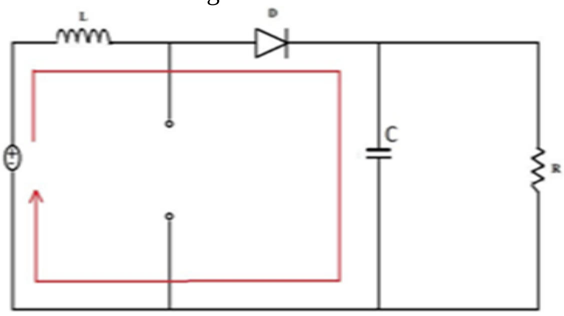

Fig. 3: Switch is off

II. Proposed Topology

A. *Without Solar*

Circuit topology from the basic topology we get voltage gain and in this topology we get increase in voltage gain. In fact, this converter uses two inductors of the same inductance level and the two switches being simultaneously used.

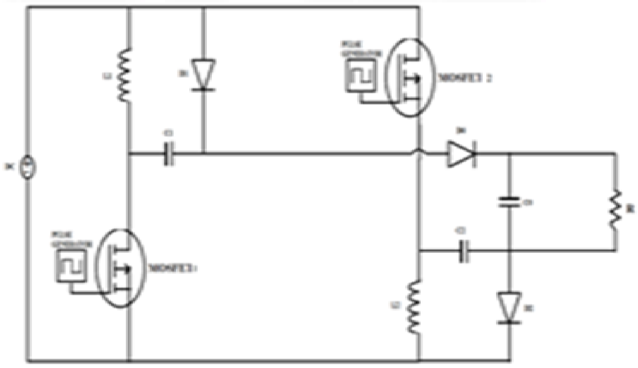
Fig. 4: Improved Circuit Topology

Circuit operation: It consists of two modes of operation.

- Mode1: When both the switches are in on state.
- Mode2: When both the switches are in off state.

B. *With Solar and MPPT*

Circuit topology For the above circuit instead of dc source solar PV panel is connected and in addition to that MPPT controller is also used.

Circuit operation: It consists of two modes of operation.

1) *Mode1: When both the switches are in on state.*

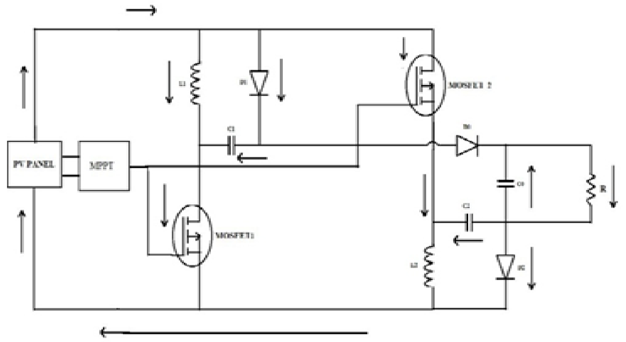

Fig. 5: When both the switches are on

2) *Mode 2: When both the switches are in off state*

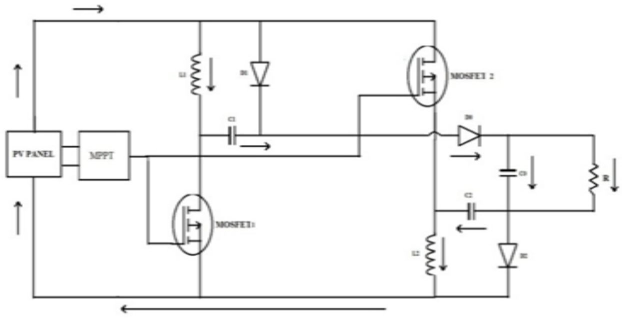

Fig. 6: When both the switches are off

III. DESIGN CONSIDERATIONS

The improved converter topology has been modeled using simulation. The simulation has been conducted to verify the performance of high step-up DC-DC converter. The circuit with the components indicated are given in the following table and used for evaluating the circuit performance.

Parameters	Values
Inductors (L1,L2)	60uH
Capacitors(C1,C2)	80uF
Output Capacitor(C0)	100uF
Resistor(R)	100 ohms
Switching Frequency	100KHz
Duty Ratio	72.72%
Input Voltage	12V

Table1: Circuit Parameters for Analysis

IV. SIMULATION RESULTS

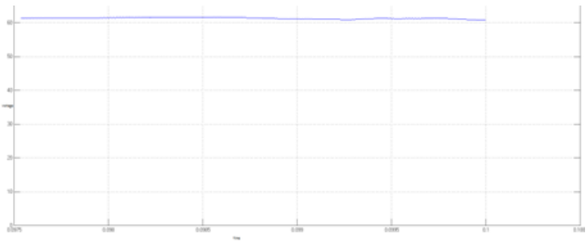

Fig. 7: Output Voltage of proposed topology

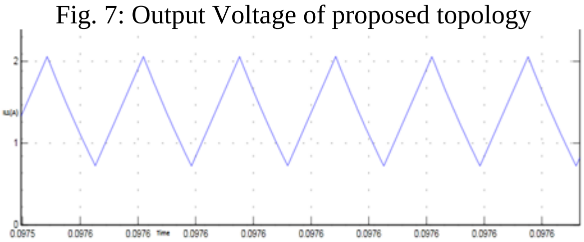

Fig 8: Inductor current through L1

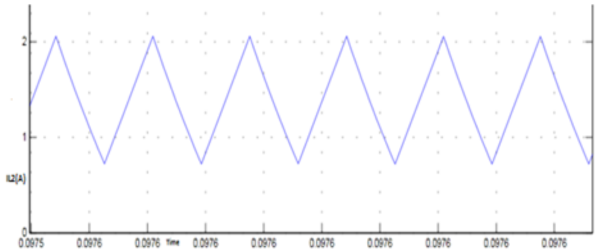

Fig. 9: Inductor current through L2

V. CONCLUSION

The performance of high step up DC-DC converter is given with simulation results for with and without MPPT. The high voltage gain is obtained for this non isolated DC-DC converter. The proposed converter has various advantages compared to basic boost converter topology. The problem of high input current at a high duty cycle overcomes in the proposed topology. The voltage stress across the switches is considerably reduced by adopting the proposed topology.

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