

High Gain DC-DC Converter for Photovoltaic Systems

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ABSTRACT: Under fast varying irradiance and load resistance a fast converging MPPT system is required to ensure the PV system response rapidly with minimum power losses. The current and voltage are sensed by the MPPT controller. This controller is used to regulate the duty cycle of the dc-dc converter. The system consists of a dc-dc converter which is connected in between PV module and the load. SEPIC converter is suited for alternative energy generation applications. An inverter is connected at the output of dc-dc converter. In order to step up the low voltage of photovoltaic panel a tapped inductor SEPIC converter is introduced. This converter has the advantages of continuous input current which can be helpful in attaining accurate tracking of maximum power point of solar panel. Therefore, features of continuous input current and as a result of lower input voltage ripple across photovoltaic can be helpful in assisting the controller tracking the maximum power point with greater accuracy.

KEYWORDS: SEPIC Converter, TI SEPIC, MPPT, Perturb and Observe method.

I. INTRODUCTION

Energy is primary and most universal measure of all kinds of work by human beings and nature. Nowadays fossil fuels are the main fuel which is being used. But there is a fear that they will get exhausted eventually in the next century. Therefore various systems based on non conventional and renewable sources are being tried in many countries. Renewable energy is the energy which comes from natural resources such as sunlight, wind, rain, tides and geothermal heat. These resources are renewable and naturally replenished. There are certain clean development mechanisms being adopted by organizations all across the globe. Renewable energy sources are known to be much cleaner and produce energy without the harmful effects of pollution. Solar energy has the greatest potential of all the sources of renewable energy and if small amount of this form of energy could be used, it will be one of the most important supplies of energy especially when other sources in the country have depleted.

Photovoltaic Cells can be used to convert solar energy directly into electricity. The advantages of solar power such as no air pollution, no fuel costs, noiseless and low maintenance [1] have boosted the demand on this type of energy. High expense in acquiring the photovoltaic module has slowed down the adoption of PV system in electricity generation. Furthermore, the power of PV module is unstable and it strongly depends on solar irradiation and load. Hence the maximum power point tracking (MPPT) is introduced to ensure the PV system to provide high efficiency inspite of the variation in solar irradiation and load resistance. Many MPPT algorithms [6] [7] have been introduced to improve the efficiency of the PV system, including fractional open circuit voltage, fractional short circuit current, perturb and observation and incremental conductance, fuzzy logic. The P&O and incremental conductance are the most popular algorithms used nowadays. When a dc-dc converter is connected in between the PV module and the load, the switching duty cycle of the dc-dc converter is regulated to ensure the PV system which always operates at the maximum power point. For the P&O method power of the PV module is determined, and then duty cycle of the converter is either increased or decreased to achieve the MPP.

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To improve the converging speed during the variation in solar irradiation level, load etc modified algorithms have been introduced. Lower dc voltages are obtained from the renewable energy sources such as solar panels, fuel cells etc. The grid connection of such resources is made possible by the electronic power inverters. Inverters are realized using a two stage power processing scheme which involves high step up dc dc front end converter followed by a grid tied dc-ac inverter. Since inverter stage requires high dc bus voltage, it may need to step up the low voltage of the solar panel tenfold or higher. Tapped inductor converters are an alternative which gives a simple circuit. The proposed converter is obtained from a basic SEPIC topology in order to attain higher voltage gain by the application of tapped inductor. The converter also has the advantage of continuous input current. Lower voltage ripple across the PV panel can be helpful in assisting the controller tracking the MPP with greater accuracy.

II. BASIC TAPPED INDUCTOR SEPIC CONVERTER

When using TI the discharge of leakage inductance into the main switch results in increased voltage spike and ringing across the switch. Therefore protective circuits can be employed which can limit the peak switch voltage across the switch. The Single Ended Primary Inductor Converter (SEPIC) [5] is capable of operating from an input voltage that is greater or less than the regulated output voltage. Aside from being able to function as both a buck and boost converter, the SEPIC also has minimal active components, a simple controller and clamped switching waveforms that provide low noise operation. The SEPIC is often identified by its use of two magnetic windings. The below Fig. 1 shows the basic circuit of tapped inductor SEPIC converter. It consists of input capacitor, coupled inductor, diode, MOSFET, output capacitor and AC capacitor.

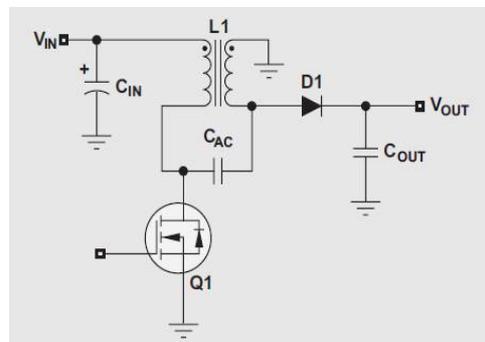


Fig.1 Basic Circuit of TI SEPIC

The input voltage is applied across the primary winding when the FET (Q1) turned on. Since the winding ratio is 1:1, the secondary winding is also imposed with a voltage equal to the input voltage. But because of the polarity of the windings, the anode of the rectifier (D1) is pulled negative and reverse-biased. With the rectifier biased off, the output capacitor is required to support the load during this ON time, which forces the AC capacitor (C_{AC}) to be charged to the input voltage. While Q1 is on, current flow in both windings is through Q1 to ground, with the secondary current flowing through the AC capacitor. The total FET current during the ON time is the addition of the input current and the output secondary current. When the FET turns off, the voltage on the windings reverses its polarity to maintain current flow. The secondary winding voltage is now clamped to the output voltage when the rectifier conducts to supply current to the output. Through transformer action, this clamps the output voltage across the primary winding. The voltage on the drain of the FET is clamped to the input voltage plus the output voltage. Current flow during the FET OFF time for both windings is through D1 to the output, with the primary current flowing through the AC capacitor.

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III. PROPOSED TOPOLOGY

The proposed topology is derived from single switch SEPIC converter. The converter comprised of an input inductor L_{in} , a buffer capacitor $C1$ and tapped inductors $L1$, $L2$. A PV module consists of number of solar cells which are connected in series or parallel and the total power generated is the sum of the power contributed by all the individual solar cells. There are various methods in modelling the PV cell and the model [4] is used to model the PV cell in this paper. Variation in the voltage and current of the PV module during solar irradiation and load voltage are considered by the MPPT controller. According to the variation in solar irradiation it will increase or decrease both the voltage and current of the module simultaneously with the duty cycle being fixed. Also with the variation in load voltage it will increase (decrease) the voltage and decrease (increase) the current of the PV module. Under load voltage variations the current variations are always in the opposite direction. The MPPT controller only regulates the duty cycle of the converter after the variation in solar irradiation and load voltage.

IV. SIMULATION RESULTS

The converter used here is the SEPIC converter. The switch control of this converter is done in a specific way (inner voltage outer current control). The voltage obtained from the MPPT is taken as reference voltage and it is compared with the actual voltage and the error voltage is given to the PI controller. The output from PI is a current reference and again compared with the actual current from the PV panel. Then this output compared and is fed to the IGBT/MOSFET in order to change according to variation in the solar irradiance and load voltage condition.

Table 1 Simulation Parameters

SI NO	Parameter	Specifications
1	Inductor L1	3900 μ H
2	Inductor L2	50 μ H
3	Capacitor C0	220 μ F
4	Capacitor C1,C3	22 μ F
5	Capacitor C2	2200 μ F

The inverter switches are MOSFETS controlled using a zoot through method. Without any other circuits, voltage can be regulated. Here the pulses for the switches are provided by voltage multiplier technique. The advantage of this method is that the converter output is taken as feedback so no need to consider another converter. The below Fig.2. shows the simulation diagram of the proposed system which consists of a PV array, MPPT control, converter, inverter and a resistive load. The above table 1 shows the simulation parameters and their specifications. Inductor $L1$ requires higher inductance than the inductor $L2$. Higher capacitance is needed to the coupling capacitor because through this capacitor energy is delivered to the load.

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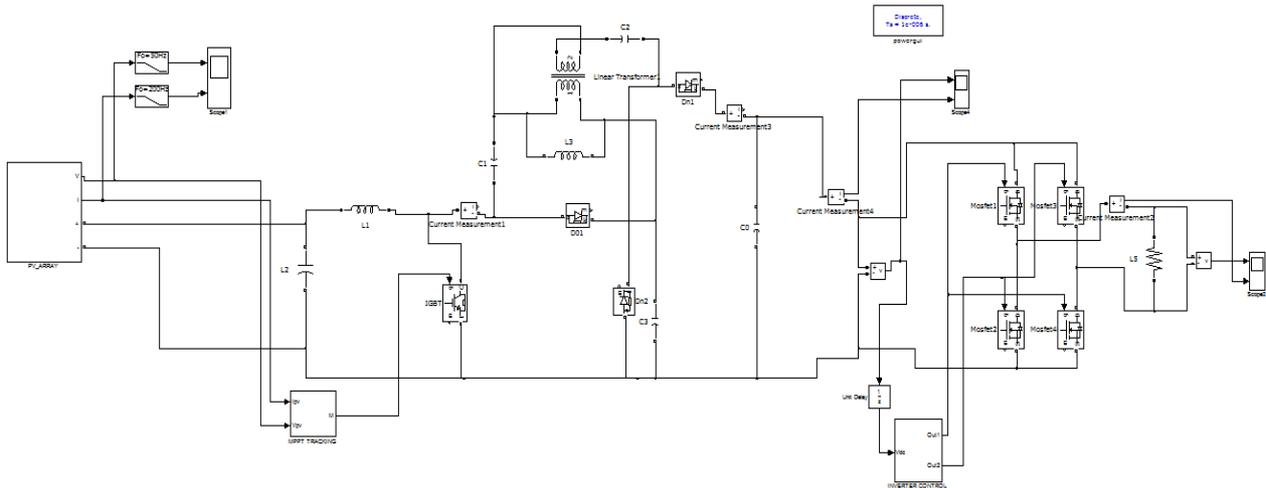


Fig.2 Simulation Diagram of the Proposed System

The input voltage obtained from PV panel is $V_{in}=14V$ and the output voltage V_{out} is obtained as $V_{out}=110V$. The inductance and capacitance values are taken as constant values. The output voltage and current waveforms of the proposed system are shown in figures 3 and 4 respectively.



Fig.3 Output Voltage and Current Waveform of the Proposed System

The above Fig.3 shows the output voltage and current waveform of the converter circuit in the proposed system and the Fig.4 shows the output voltage and current waveform of the inverter circuit.

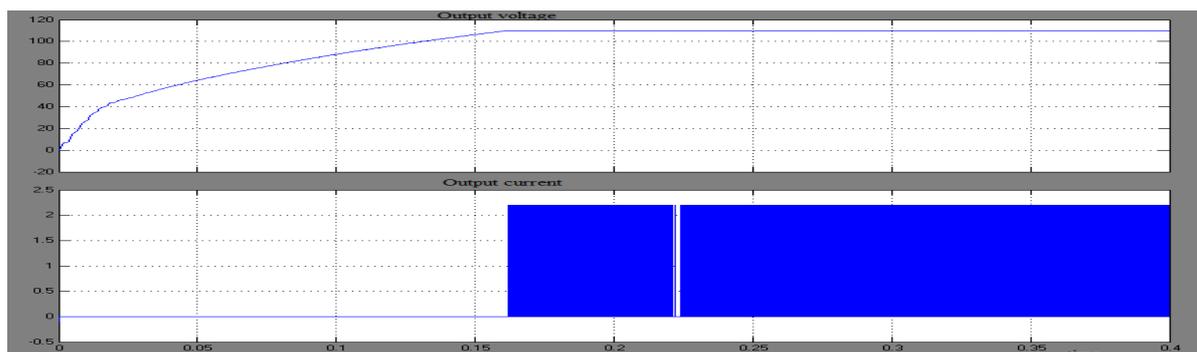


Fig.4 Output Voltage and Current Waveform of the Converter

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V. CONCLUSION

In photovoltaic applications the pulsating input current periodically shifts the operating point and makes it difficult to precisely track the maximum power point. This paper introduces a TI SEPIC converter and charge pump techniques. The system requires a tapped inductor to boost up the low voltage of the solar panel. The algorithm proposed responds fastly to the variation in solar irradiation and load voltage variation. There is no steady state oscillations in the proposed algorithm and thus reduces the power losses.

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