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Efficiency Enhancement of Centralized PV Street Lighting System Using Single-Ended Primary Inductance Converter by reducing input ripple contents

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Abstract

Decentralized or centralized off-grid solar street lighting systems are those systems that have been developed to meet the needs of the low or no-isolation period. These systems operate, even if the weather conditions are bad. The central station can perform as micro power distribution center. More -over, the system is easy and inexpensive. The efficiency of the system is therefore the most important factor in a power distribution system, the efficiency of the system depends on centralized system power distribution architecture and distributed systems. Buck and boost converters have been used in the central system as well as in decentralized PV streetlights. Buck converter is used to step down, while the boost converter is used to step up the voltage. The buck and boost converter requires a single capacitor and an inductor. But the first problem in this transducer that it suffers from a high amount of current ripple content due to its ripple harmonics or high frequency oscillation noise generating. 2nd problem is that Buck and boost converters operating causes large amounts of electrical stress on the components, this can be equipment failure or overheating exists. In this paper, the new DC-DC Single Ended Primary Inductance Converter with new technology switch regulator will be analyze and simulated to reduce the input current ripple contents to enhance the efficiency of PV street lighting system.

Introduction

Recently PV systems have found fairly broad applications. Grid of small scale PV reaches about a few tenths Watts in applications such as camera, watches, Mobile phones, etc. One of these applications is the PV standalone systems as the most economical solution to the disposal required power service. Street lighting system that most the efficient and low-cost High Bright led is one of them Standalone PV systems applications. This system consists of PV - panel, high-quality battery, High Bright LED, DC-DC converter and the controller as shown in figure 1.

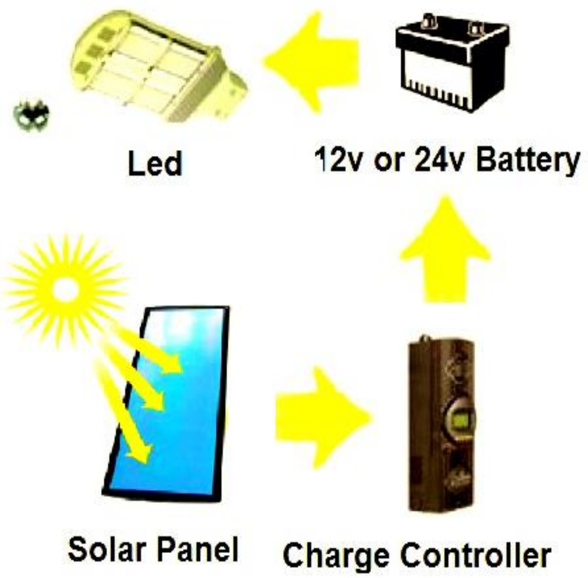

Figure1. PV Street Lighting System with Charge Controller

PV system is not only an environmentally friendly option (Requires no power input and free of pollution), but can also anywhere, regardless of the local network availability being. That Solar energy is recognized as an environmentally ' clean ' form of energy production point of view. PV systems use solar radiation to produce electricity. These modules do not require fuel to work. Solar energy is very cost effective and the energy problems without reducing the national grid services. This solar energy offers a reliable and secure energy supply to cities and rural areas. Solar home lighting solutions and solar street lighting are widely used in developed countries used and they are trying national network services to replace renewable energy.

ISSN:2319-7900

Providing street lighting, for example, one of the most important factor, and also a responsibility for the community / village system to both pedestrians to improve safety and comfort and vehicle traffic. This solar energy system also provides an efficient and improved sense of security to the village community. The decentralized solar LED street lighting functions independently of the power grid.

The Renewable Energy so solar energy is used to charge a battery during the day time and then charged battery switch on the LED light during night time. The battery capacity is usually designed to meet light loads under varying ambient conditions, and is often oversized. This system have high initial costs, but its operation time is 16 to 22 years. This system can be designed to achieve the requirements of the local requirements. The solar energy can be used for charging electric vehicle battery in street lighting system of this energy and can be used in the daytime to fir household appliances can be used. This solar power station can also work as a micro power distribution center. In a future grid load station can be moved to this central or micro power distribution center. The centralized system maintenance and operation is very simple.

PRESENT CENTRALIZED PV STREET LIGHTING SYSTEM

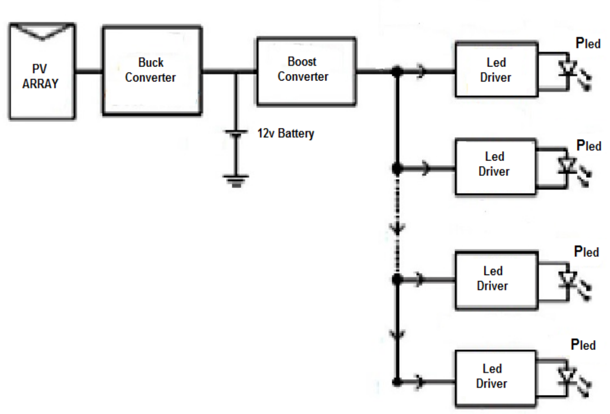

Figure 2. Present PV street lighting system

In Figure 2, buck converter was used to step down the input voltage working as a Maximum power point tracker.

While after charging the 12v battery, the boost converter boost the input voltage from 12v to 24v to drive the high bright white leds.

Their parameters are given below:

Parameters	Values
Input Voltage	Varies from 14v to 20v
Output Voltage	Fixed by Battery voltage 12v
C,L	200uF,200uH
Switching Frequency	5MHz Max
Duty Cycle	5% to 95%
Efficiency	87%

Table 1. Buck Converter Parameters and Values

Parameters	Values
Input Voltage	Fixed by battery voltage 12v
Output Voltage	24v
C,L	50Uf,400mH
Switching Frequency	5MHz Max
Duty Cycle	5% to 95%
Efficiency	94%

Table 2. Boost Converter Parameters and Values

One of the converter i-e (buck converter) was implemented in the Matlab/Simulink and analyzed that there are input current ripple contents approximately 3A, which makes stress on the components cause system failure or overheating. The graph are given below.

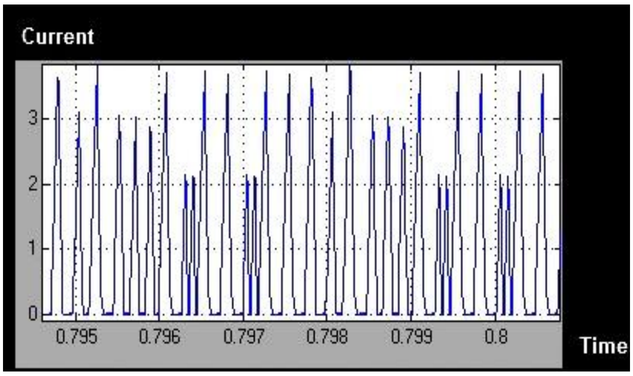

Figure3. Input Ripple Current of Buck Converter

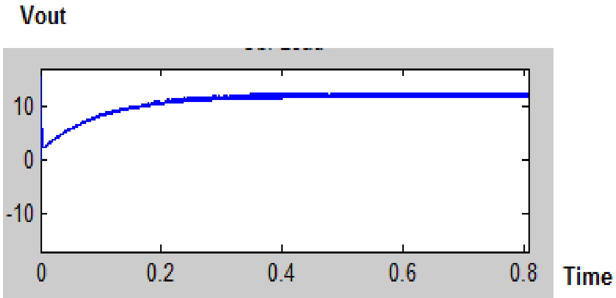

Figure 4. 12V output voltage of buck converter

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Proposed Block Diagram

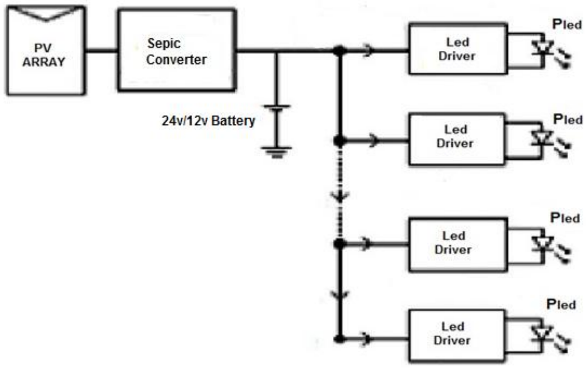

Figure 5. Proposed PV street lighting system

In the Figure 5, SEPIC converter is replaced with buck and boost converter to minimize the complexity, to reduce the input current ripple contents and to reduce the cost.

Sepic Converter

The SEPIC converter output voltage will be greater than, less than or equal to that at its input. It is a type of DC-DC converter. The output of the SEPIC converter output is controlled by the transistor duty cycle.

The amount of energy in the SEPIC converter exchanged between the inductors and capacitors to convert from one voltage to another that is controlled by the switch i-e MOSFET or IGBTs. MOSFETs offer much higher input impedance and low voltage drop of bipolar transistors (BJTs) and do not require biasing resistors as a MOSFET switch is controlled by the differences in voltage rather than a current, as in BJTs).

There are two modes in SEPIC converter i-e continuous mode and discontinuous mode.

In continuous conduction mode, the current in the inductor L1 never falls to zero. While in the discontinuous mode, the current in the inductor L1 falls to zero.

Working Principle of Single Ended Primary Inductance

In Figure 6, when the switch SW is turned on, current IL1 increases, and the current IL2 goes negative. (Mathematically, it reduced due to the direction of the arrow). The energy to increase the current IL1 comes from the input source. Since SW is closed for a short time and the instantaneous voltage VCs is approximately equal to VIN and the voltage VL2 is approximately equal to -VIN. Therefore, the capacitor Cs provides the energy to increase the amount of current in IL2 and thus the stored energy in L2. The easiest way to visualize this is by the biases of the circuit in a direct look at state and close SW.

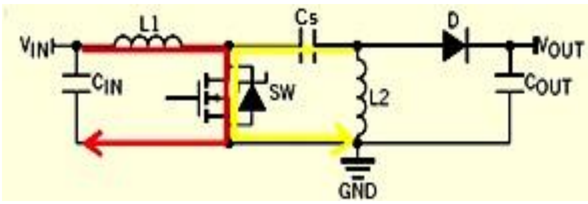

Figure 6. When Mosfet switch SW turn ON

In Figure 7, when the switch SW is turned off, the current ICs is the same as the current IL1, since inductors to allow no instantaneous current changes. It can be from the diagram that a negative IL2 to the current IL1 is supplied the current to the load increase can be seen directory. IL2 - With Kirchhoff's current law, it may, that ID1 = ICs displayed. It can be concluded that, while SW is turned off, supplied power to the load from both L2 and L1. Cs, however is being charged by L1 during this off cycle, and will in turn recharge L2 during the on cycle.

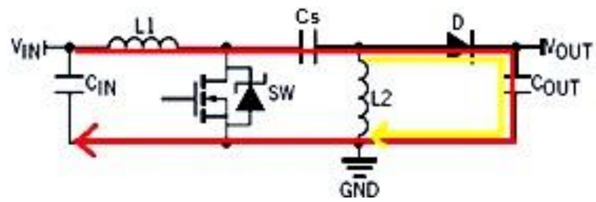

Figure 7. When Mosfet switch SW turn OFF

Required Components in SEPIC Converter

Schottky diode will be used in place of simple diode in the SEPIC converter because is used in fast switching applications. In addition, Schottky diodes characterized by low forward voltage lower compared with the PN junction diodes regular silicon. It may be a voltage drop somewhere between 0.15 and 0.4 volts at low currents, compared with 0.6 volts bilateral silicon diode. To achieve that performance, these diodes are different from regular diodes, and constructed with metal contact to the semiconductor. Schottky diodes are used in wireless applications, clamping diodes and rectifier applications.

Ceramic capacitor will be used at the input side. It is also used in DC- DC converters, which put a lot of pressure on the plug-in high frequency and high levels of electrical noise form. Ceramic capacitors can also be used intensively for general purpose, because it is not polarized and are available in a large variety of capacity, and evaluate the effort and sizes. Many amateur, especially in the field of robotics, familiar with ceramic disc capacitors used throughout the brush DC motors to reduce noise RF. A ceramic capacitor is a constant value intensive working as a ceramic dielectric. It is constructed of two or more alternating layers of ceramic and metal layer acting as electrodes. Composition of ceramic material determines the electrical behavior and therefore applications. Ceramic capacitors provide low losses and high stability resonant circuit applications. These capacitors provide bypassing high volumetric efficiency of the buffer, and coupling applications.

New linear technology-1370 is the ultralow noise Switching regulator will be used in place of single MOSFET. The LT1370 is a high frequency current state switching regulator. A 6A high efficiency switch on the chip along with all oscillator, control and protection circuit.

The LT1370 typically consumes only 4.5mA rest Current and has a higher efficiency. This Switching regulator has a built-in MOSFET and also used as voltage regulator.

Calculation of Components in SEPIC Converter

Calculate Min Inductance

Proposed system parameters are given below:

Vin = 14/20 Vout = 24,

I out = 1A Vd = .7

Vin is Input voltage, Vout is Output voltage, Iout is Output current and Vd is the voltage drop across diode. Fsw i-e switching frequency of Lt1370 switching regulator is 500 KHz.

$$Max\ duty\ cycle = \frac{\mathrm{Vout + Vd}}{\mathrm{Vi.min + Vout + Vd}} \quad (1)$$

$$\text{Max duty cycle} = \frac{24 + .7}{14 + 24 + .7}$$

= .626

$$L1 = L2 = L = \frac{\mathrm{Vi.min \times Dmax}}{\mathrm{Iout \times Fsw}} \quad (2)$$

$$L1 = L2 = L = \frac{14 \times .626}{1\mathrm{A} \times 500{,}000}$$

L = 17.2uH

Selected component= 50uH

Cin Capacitor

The RMS current of the C1 is:

$$= \mathrm{Iout} \times \sqrt{\frac{\mathrm{Vout + Vd}}{\mathrm{Vi.min}}} \quad (3)$$

$$= 1\mathrm{A} \times \sqrt{\frac{24 + .7}{14}}$$

=1.7A

The ripple voltage is:

$$= \frac{\mathrm{Iout \times Dmax}}{\mathrm{Cs \times Fsw}} \quad (4)$$

$$= \frac{1\mathrm{A} \times .626}{10\mathrm{uF} \times 500{,}000}$$

= 0.1V

Selected component is ceramic cap 10uF.

Output Min Capacitor

$$= \frac{\mathrm{Iout \times Dmax}}{\mathrm{Vripple \times Fsw}} \quad (5)$$

$$= \frac{1\mathrm{A} \times .626}{0.02 \times 500{,}000}$$

= 62uf

Selected component= 100uf

Calculate Positive output voltage regulation resistors

LT1370 and development of signal 1.245V (Vref) from FB pin to the ground. It has been appointed the

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output voltage by connecting FB pin to output resistor divider. FB pin bias current represents a small error and can usually be disregard for the values of R2 even 7K.

$$= \mathrm{R2} \times \left(\frac{\mathrm{Vout}}{\mathrm{Vref}} - 1\right) \qquad (6)$$

$$= 6 \times \left(\frac{24}{1.245} - 1\right)$$

=109 ohm.

Selected components are

R1=109ohm and R2=6ohm

Calculate ripple current

$$= \frac{\mathrm{Vi.min} \times \mathrm{Vd}}{\mathrm{L} \times \mathrm{Fsw}} \qquad (7)$$

$$= \frac{14 \times .7}{50\mathrm{uH} \times 500{,}000}$$

= 300mA

Simulated Circuit

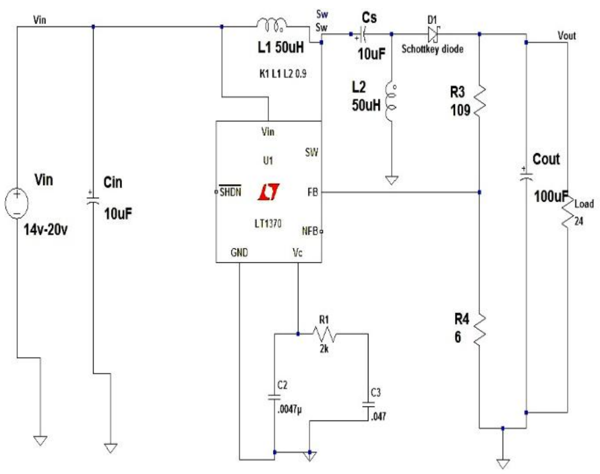

Figure 8. Simulated Circuit of SEPIC Converter in Ltspice Software

In Figure 8, .047uF capacitor is used at pin Vc to reduce the switching frequency ripples to a few mV. SW is the switching pin is the collector of the power switch (MOSFET) and has flown through large currents. Keep the trace with switching components as short as possible, to minimize radiation and voltage spikes.

FB is the feedback pin used to regulate the output voltage. Input capacitor 10uF or higher value should be used to handle RMS current.

Vin is the variable dc power supply act as a 20v solar Panel. If the input voltages changes, the output will always be regulate.

Results

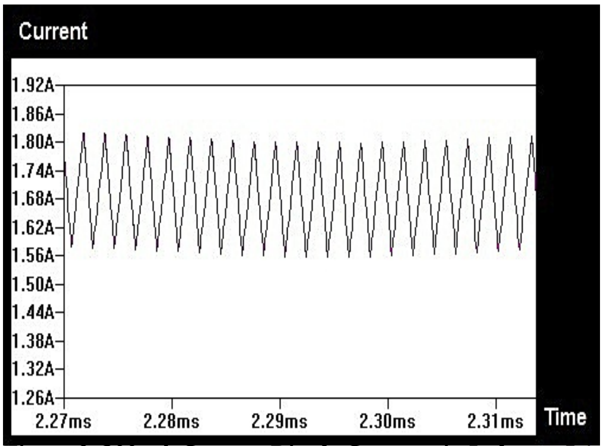

Figure 9. 200mA Current Ripple Contents in Inductor L1

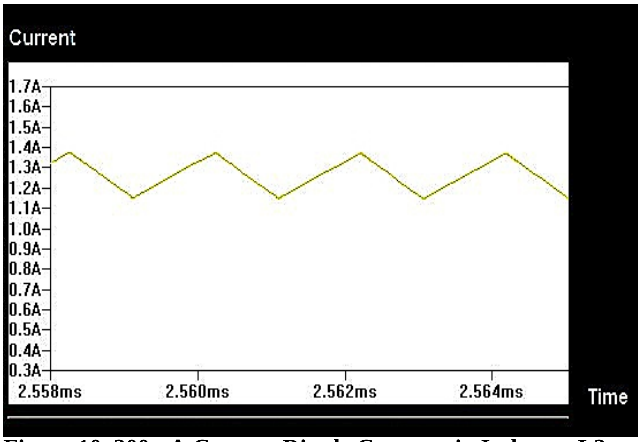

Figure 10. 200mA Current Ripple Contents in Inductor L2

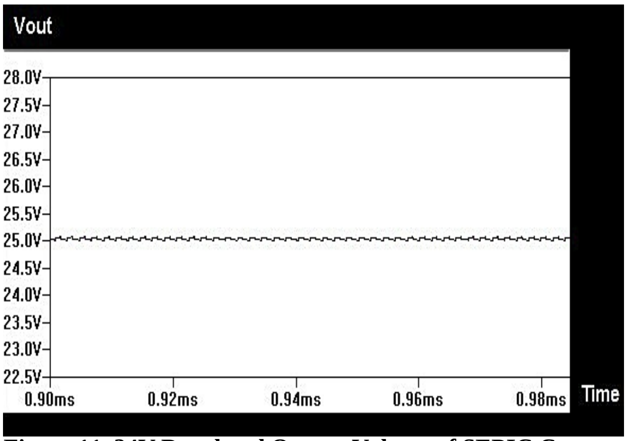

Figure 11. 24V Regulated Output Voltage of SEPIC Converter

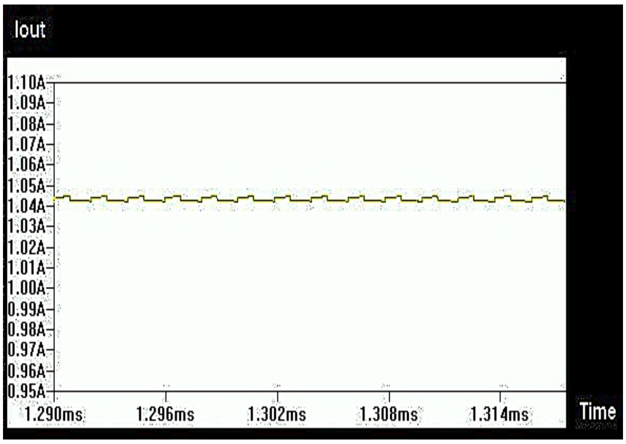

Figure 12. 1A Output Current of SEPIC Converter

As shown in Figure 9 and 10, input current ripple Contents is reduced to 200mA.The output voltage and output current is regulated as shown in Figure 11 and 12. So SEPIC con

verter is very efficient and can be used in place of buck and boost converter.

Conclusion

The proposed PV street lighting system is cheaper than the present PV Street lighting system. SEPIC converter is more and more important in battery-powered systems and using new technology switching regulator Lt1370 with SEPIC converter, the input current ripple contents is minimized. The system complexity is minimized. The cost is reduced.

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Biographies

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