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Design of a Closed Loop System Using Modified SEPIC

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Abstract— **The modified SEPIC converter introduces a change in the positioning of the transistor switch. The objective of this paper is to prove that this reduces oscillations and further provides better stability to the system as the load will be connected to the source at all times. However in the process the converter loses its boosting capability. Here the modified SEPIC converter is shown to be integrated with a solar powered system. The closed loop uses the Maximum Power Point Tracking (MPPT) algorithm to get the best possible efficiency at the given intensity. The simulation results of modified SEPIC converter are obtained with PI controller for the output voltage.**

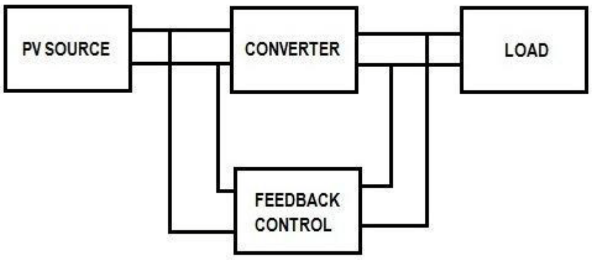
Attempts to achieve stability have been made, some suggesting that stable current controlled SEPIC can be achieved by selecting passive components carefully. However this modification suggests a different way to achieve stability.

Index Terms— **MPPT, SEPIC**

INTRODUCTION

The present energy scenario warrants the use of renewable sources. Solar energy is one of the most available sources of renewable. However a very small percentage of the total available energy resource is found to be harnessed. The major factors inhibiting the use of this vast resource are the low efficiency obtained and the variation in the intensity of the source. Although efforts have been made and significant advances have come about in improving efficiency, the high cost incurred prevents widespread use of solar energy as a source for day to day applications. (Enter Stats)

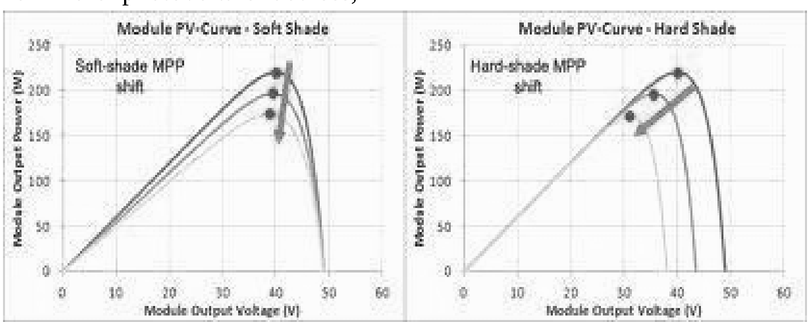
I. SYSTEM REPRESENTATION



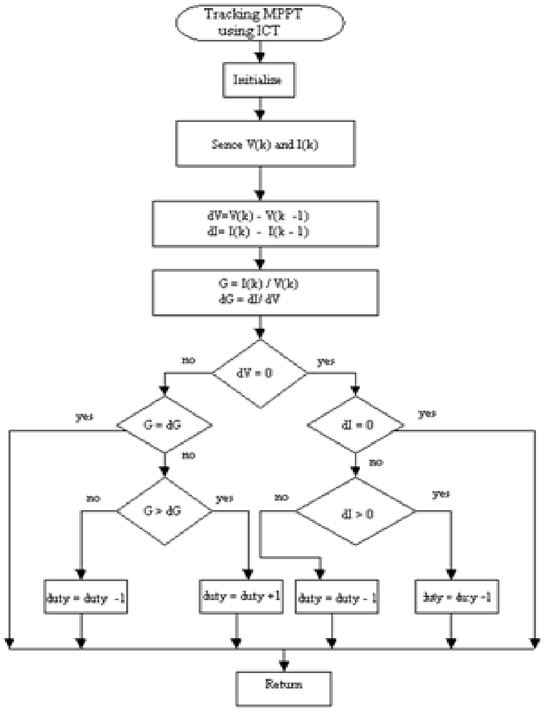
The PV source provides a varying output voltage which depends upon the intensity of sunlight. Hence, a converter in the forward path enables a constant output voltage. The feedback control loop helps to achieve maximum efficiency.

II. FEEDBACK CONTROL

The control is achieved using MPPT. Maximum power point tracking (MPPT) is a technique that grid-tie inverters, solar battery chargers and similar devices use to get the maximum possible power from one or more photovoltaic devices, typically solar panels, though optical power transmission systems can benefit from similar technology. Solar cells have a complex relationship between solar irradiation, temperature and total resistance that produces a non-linear output efficiency which can be analyzed based on the I-V curve. It is the purpose of the MPPT system to sample the output of the cells and apply the proper resistance (load) to obtain maximum power for any given environmental conditions.



The algorithm used in this case is the incremental conductance algorithm.



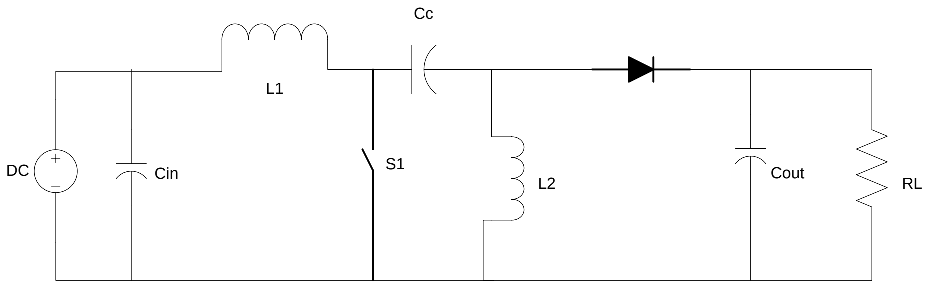
III. SEPIC CONVERTER AND ITS DRAWBACKS

Single-ended primary-inductor converter (SEPIC) is a type of DC-DC converter allowing the electrical potential (voltage) at its output to be greater than, less than, or equal to that at its input; the output of the SEPIC is controlled by the duty cycle of the control transistor.

A SEPIC is similar to a traditional buck-boost converter, but has advantages of having non-inverted output (the output has the same voltage polarity as the input), using a series capacitor to couple energy from the input to the output (and thus can respond more gracefully to a short-circuit output), and being capable of true shutdown: when the switch is turned off, its output drops to 0 V, following a fairly hefty transient dump of charge.

The SEPIC converter’s popularity is due to its ability to operate from an input voltage that is greater or less than the regulated output voltage. This capability allows it to be used in many non-isolated applications such as automotive, medical, security systems, and LED lighting. SEPICs also find application in the power supplies for power-factor converters (PFCs).

SCHEMATIC OF THE SEPIC



Operation of SEPIC

A SEPIC is said to be in continuous-conduction mode ("continuous mode") if the current through the inductor L1 never falls to zero. During a SEPIC's steady-state operation, the average voltage across capacitor C1 (V_{C1}) is equal to the input voltage (V_{in}). Because capacitor C1 blocks direct current (DC), the average current across it (I_{C1}) is zero, making inductor L2 the only source of load current. Therefore, the average current through inductor L2 (I_{L2}) is the same as the average load current and hence independent of the input voltage.

Looking at average voltages, the following can be written:

$$V_{IN} = V_{L1} + V_{C1} + V_{L2}$$

Because the average voltage of V_{C1} is equal to V_{IN}, $V_{L1} = -V_{L2}$. For this reason, the two inductors can be wound on the same core. Since the voltages are the same in magnitude, their effects of the mutual inductance will be zero, assuming the polarity of the windings is correct. Also, since the voltages are the same in magnitude, the ripple currents from the two inductors will be equal in magnitude.

The average currents can be summed as follows:

$$I_{D1} = I_{L1} - I_{L2}$$

When switch S1 is turned on, current I_{L1} increases and the current I_{L2} increases in the negative direction. (Mathematically, it decreases due to arrow direction.) The energy to increase the current I_{L1} comes from the input source. Since S1 is a short while closed, and the instantaneous voltage V_{C1} is approximately V_{IN}, the voltage V_{L2} is approximately $-V_{IN}$. Therefore, the capacitor C1 supplies the energy to increase the magnitude of the current in I_{L2} and thus increase the energy stored in L2. The easiest way to visualize this is to consider the bias voltages of the circuit in a d.c. state, then close S1.

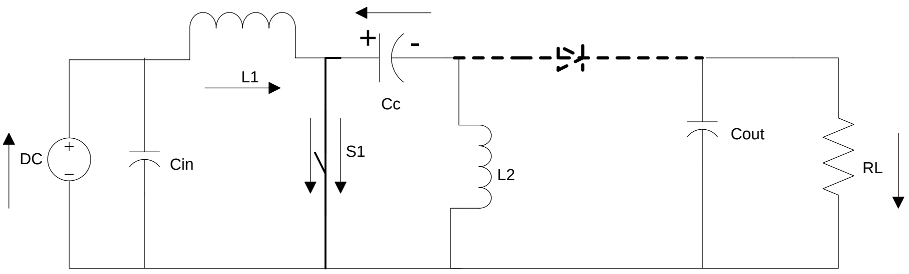


Figure 2: With S1 closed current increases through L1 and Cc discharges increasing current in L2

When switch S1 is turned off, the current I_{C1} becomes the same as the current I_{L1}, since inductors do not allow instantaneous changes in current. The current I_{L2} will continue in the negative direction, in fact it never reverses direction. It can be seen from the diagram that a negative I_{L2} will add to the current I_{L1} to increase the current delivered to the load. Using Kirchhoff's Current Law, it can be shown that $I_{D1} = I_{C1} - I_{L2}$. It can then be concluded, that while S1 is off, power is delivered to the load from both L2 and L1. C1, however is being charged by L1 during this off cycle, and will in turn recharge L2 during the on cycle.

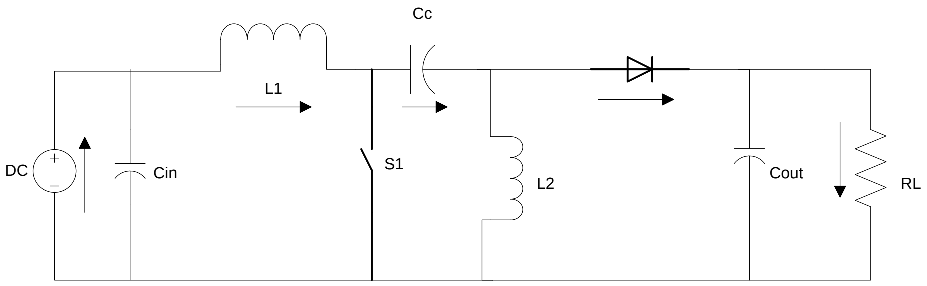


Figure 3: With S1 open current through L1 and current through L2 produce current through the load

Because the potential (voltage) across capacitor C1 may reverse direction every cycle, a non-polarized capacitor should be used. However, a polarized tantalum or electrolytic capacitor may be used in some cases,because the potential (voltage) across capacitor C1 will not change unless the switch is closed long enough for a half cycle of resonance with inductor L2, and by this time the current in inductor L1 could be quite large.

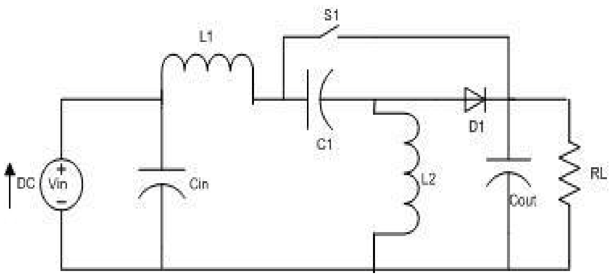
The capacitor C_{IN} is required to reduce the effects of the parasitic inductance and internal resistance of the power supply. The boost/buck capabilities of the SEPIC are possible because of capacitor C1 and inductor L2. Inductor L1 and switch S1 create a standard boost converter, which generates a voltage (V_{S1}) that is higher than V_{IN}, whose magnitude is determined by the duty cycle of the switch S1. Since the average voltage across C1 is V_{IN}, the output voltage (V_O) is V_{S1} - V_{IN}. If V_{S1} is less than double V_{IN}, then the output voltage will be less than the input voltage. If V_{S1} is greater than double V_{IN}, then the output voltage will be greater than the input voltage.

The evolution of switched-power supplies can be seen by coupling the two inductors in a SEPIC converter together, which begins to resemble a Flyback converter, the most basic of the transformer-isolated SMPS topologies.

Drawbacks of the SEPIC are :

1. SEPIC converter has pulsating output current similar to buck-boost converters.
2. Since the SEPIC converter transfers all its energy via the series capacitor, a capacitor with high capacitance and current handling capability is required.
3. The fourth-order nature of the converter also makes the SEPIC converter difficult to control, making them only suitable for very slow varying applications.

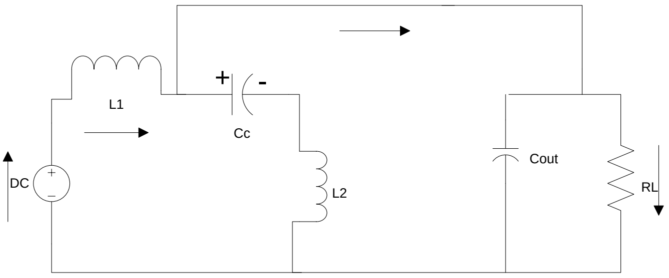
IV. MODIFIED SEPIC CONVERTER



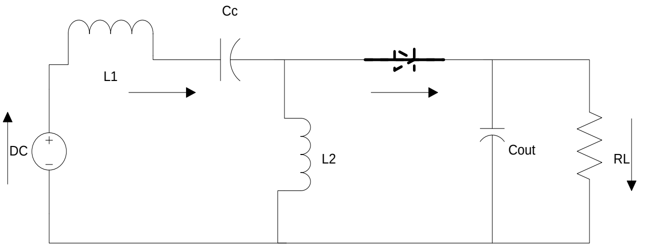
The above modification introduces a change in the positioning of the switch. This new positioning ensures that the load is connected to the source at all times.

We thus can consider two modes of operation for our modified circuit.

Case I: During this mode the switch S1 is closed. Initially, the capacitor C1 is charged with the plate nearer to the source having a positive charge. The load is supplied from the inductors L1 and L2 through the S1 loop. The capacitor discharges as the load is supplied.



Case II: During this mode the switch S1 is assumed open. Thus the load is supplied from inductors L1 and L2 through the diode D1 which is forward biased. During this time the capacitor C1 charges with same polarity as in Case I.



The above cases repeat depending on the state of switch S1.

Table Head	Comparison of simulation results		
	Parameters	***SEPIC***	***Modified SEPIC***
1.	Current (A)	3.8	4
2.	Voltage (V)	48	50
3.	Power (W)	200	197

V. CONCLUSION

When the PV array is used as a source of power supply, it is necessary to use the MPPT to get maximum efficiency from the PV array. The MPPT is implemented by means of a programmed microcontroller and is designed to operate such that the oscillations in the output are significantly reduced and achieves a steady state value closer to the desired output. The drawback of this scheme is that the boosting capability of the SEPIC is lost. However, further studies on this configuration of the SEPIC could overcome this drawback.

VI. ACKNOWLEDGMENTS

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