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PERFORMANCE EVALUATION OF SEPIC CONVERTER

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Abstract*:* In modern era different portable electronic equipment is beneficial from a power converter which is having high efficiency with a wide input and output voltage ranges with a compact size. But conventional power converter can't able to maintain a wide operation range with high Efficiency, especially when up-and-down voltage is required. These characteristics can be obtained in a single ended primary inductor converter (SEPIC). The single-ended primary inductor converter (SEPIC) is a type of DC/DC converter which allows voltage at its output to be greater than, less than, or equal to than at its input voltage. The output of the SEPIC is controlled by the duty cycle of the control transistor/IGBT/MOSFET. This Paper goes into detail of simulation of open loop & closed loop control for the SEPIC converter in MATLAB & results is analysed

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I INTRODUCTION

The power converters are the electronic circuits which are used for the conversion, control and conditioning of electric power. Single Ended Primary Inductor Converter (SEPIC) is a DC-to-DC converter and is capable of operating in either step up or step-down mode and widely used in battery operated equipment by varying duty cycle of gate signal of MOSFET. It can step up or step-down voltage. For Duty cycle above 0.5, it will step up and below 0.5, it will step down the voltage to required value. Various conversion topologies like Buck, Boost, Buck-Boost are used to step up or step-down voltage.

Some limitation like pulsating input and output current, inverted output voltage, in case of Buck converter floating switch make it unreliable for different application. So, it is not easy for conventional power converter design to maintain high efficiency especially when it step up or step down voltage. All these characteristics are obtained in SEPIC DC to DC power conversion. Different designs are used using active and passive components. Non-inverted output, low equivalent series resistance (ESR) of coupling capacitor minimize ripple and prevent heat built up which make it reliable for wide range of operation.

INDRODUCTION TO SEPIC CONVERTER:

The most common technology in all the electronic converters is switched mode power converters. Switched mode power converters convert the voltage input to another voltage signal by storing the input energy and then releasing that energy to the output at a different voltage as per switching operation. The most common classification of power conversion systems is based on the waveforms of input and output signals. Thus, power converters are classified as AC to DC converters, DC to AC converters, AC to AC converters and DC to DC converters. There are different kinds of DC-DC converters used for several years for different applications. Some of the applications require high voltages while some require low voltages. Depending on the application DC-DC converters are divided as Buck converters, Boost converters, Buck-Boost converters, Cuk converters and SEPIC converters. The brief introduction of these DC-DC converters is introduced in this section. In Buck converter,

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the average output voltage is less than the input voltage.

Buck converter is made of a voltage source, a switch, a diode, an inductor, a capacitor and a resistive load. This converter is also called the step-down converter because the voltage across the Inductor opposes supply voltage. The circuit diagram of Buck converter is shown in Fig 1.1

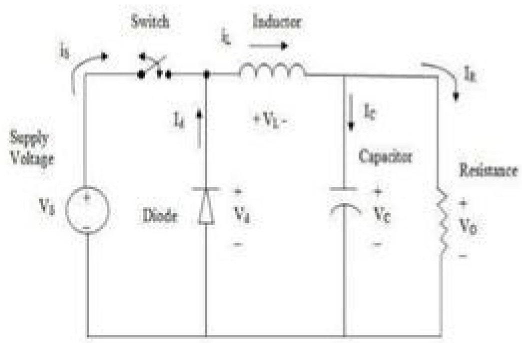

Fig.1.1 Buck Converter

When switch turns on current flows from the source through switch to Inductor, then Capacitor and finally to the Resistive load. As current flows through Inductor, a magnetic field is build up, causing energy to be stored in the Inductor. When switch is turned off, energy stored in the Inductor supplies current to the Resistive load through Diode. The voltage across the load (V0) is a fraction of input voltage (VS). This fraction is known as Duty cycle (D). Thus the output voltage(V0) of Buck converter can be varied as the fraction of input voltage (VS) by varying the Duty cycle(D).

The Boost converter has similar structure as the Buck converter, only the difference is that it has components arranged in different manner. The output of Boost is always greater than input voltage (VS) therefore the Boost converter is used when higher output voltage (V0) is required than the input voltage (V0). It is also known as step up converter because the Voltage across Inductor adds to the input supply voltage (V0) to step-up the voltage above input voltage (V0). Fig 1.2. shows the circuit diagram of Boost converter.

When the switch is turned on current flows through the Inductor and switch, thus storing the energy in the Inductor in magnetic field. There is no current flowing through Diode and the load current is supplied through the charge stored in Capacitor.

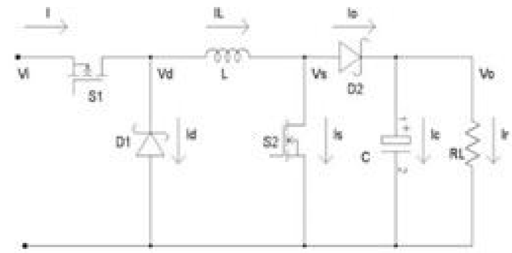

Fig.1.2. Boost Converter

When switch is turned off, the Inductor opposes any drop in current. Thus, the Inductor voltage adds to the source voltage (VS), thus stepping up the output voltage (V0). The current now flows from the source through Inductor, Diode and the Load resistance, and then charging the Capacitor again. The Buck Boost converter is the combination of Buck and Boost converter. The components of Buck-Boost converter are similar but arranged in different way to provide stup and step down voltage.

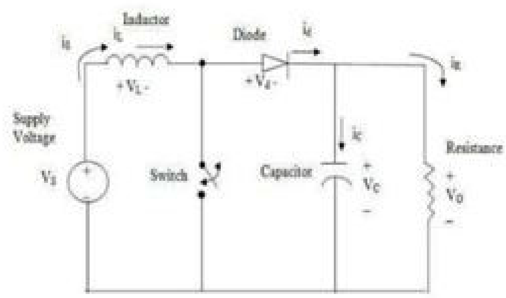

Fig 1.3 Buck-Boost converter

When the switch is turned on, there is path between the Inductor (L) and voltage source (Vi). As current flows through the Inductor (L), energy is stored in magnetic field. The Diode (D1) is reverse biased so no current flows through the Diode (D1) to the Load. The Capacitor (C) supplies the load current. When the switch is turned off, the path between the Inductor (L) and voltage source (Vi)Is broken. The stored energy in the Inductor (L) generates a voltage which forward biases the Diode (D)1 and current flows into Load and Capacitor cause recharging the capacitor. The Buck, Boost and Buck-Boost converters all transfer the energy between input and output using the

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Inductor, thus building the voltage across the Inductor.

Whereas the Cuk converter transfers the energy through the Capacitor. The output of Cuk converter is inverted and the circuit configuration is the combination of Buck and Boost converters as in Buck-Boost converter. Fig 1.4. shows the block diagram of Cuk converter.

Fig. 1.4. Cuk Converter

When the switch is turned on, the path of switch is shorted whereas the Diode (D) is open circuited. The current flows through Inductor (L) and energy is stored in magnetic field in Inductor(L). When switch is turned off, thus the path across the switch is open circuited. The Diode (D)conducts and the current flows from voltage source, through Inductor (L), Diode (D) and charging capacitor (C0) by transferring to it some of the energy that was stored in Inductor (L). When switch is turned on again, Capacitor (C0) discharges through Inductor (L0) into the Load, with Inductor (L0) and Capacitor (C0) acting as smoothing filter, whereas at the same time energy is being stored in Inductor (L).

II BASICS OF SEPIC CONVERTER

The basic converter in day to-day life is buck converter. It is so called, because it only steps down the input voltage. The output is given by

$$V_o = DV_s \qquad (1)$$

Where V_o = output voltage

V_s = input voltage

D = duty cycle

By interchanging input and output Boost converter is obtained. This converter only step up voltage, hence its name Boost. The output is always greater than input, but main problem is to get step up and step down voltage from a single device depending on output. So two cascaded converters (a Buck and a Boost) are used. But for this two separate controller and separate switch are required. So it is not the good solution. Buck-Boost converter can give required output but here output is inverting. These converters have more component stresses, component sizes and lesser efficiency.

To reduce the losses caused by high voltages, a circuit with buck-boost conversion characteristics, small energy storage element required and smaller inductor size is desired such that ripple current is high. Thus, the optimum converter however should have low component stresses, low energy storage requirements and size and efficiency performance comparable to the Boost or the Buck converter. One converter that provides the required output is the SEPIC (Single Ended Primary Inductor Converter) Converter. By varying Duty cycle of gate signal of MOSFET output can be varied. If Duty cycle is greater than 50% it will step up, so it is called boost converter.

If Duty cycle is below 50% it will step down the voltage and it operate as Buck converter. Another advantage of this converter is it provides a positive regulated output voltage from an input voltage that varies. It functions as both like a buck and boost converter, the SEPIC also has minimal active components, a simple controller that provides low noise operation.

III DESIGN AND COMPONENTS OF SEPIC CONVERTER

1. MOSFET Decisions and Parameters

In order to complete the buck converter, a transistor had to be selected. A transistor is defined by Dictionary.com as “a semiconductor device that amplifies, oscillates, or switches the flow of current between two terminals by varying the current or voltage between one of the terminals”. There are different types of transistors, such as Bipolar Junction Transistors (BJT) or Field Effect Transistors (FET). Our team decided to use an N-MOSFET (NMOS for short). The parameters we needed to pay close attention to where the drain to source breakdown voltage, resistance, and drain current. The drain to source breakdown voltage needed to be greater than 20V, because the solar panel would have an output of 20V. The resistance needs to 21 below in order to reduce conduction losses. To find the needed minimum value for the drain current, the current flowing through the inductor needed to be calculated. The output power for the solar

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panel is 0.2W. The output voltage for the DC/DC buck converter is 10V. Using the equation

$$iL = P/V$$

the above numbers were filled into find the inductor current.

$$iL = P/V = .2W\ 10V = 20mA$$

2. Design Modification

Although during the design and simulation phases everything went smoothly with the original design, during implementation phase it was necessary for the design to be slightly modified due to the chosen components and its manufacturer. The modifications that were made to the original design are the buck converter switch, and the output reading from the buck the converter to the Arduino.

3. MOSFET Switch

Within the buck converter there is an electronic switch that closes and opens based on the input PWM, refer to the figure below for the equivalent circuit when the switch is closed and 22 open. During the simulation, at the switching state of the buck converter, since the chosen component was the ideal MOSFET, there wasn't any signs of design errors. However, during implementation phase, the gate-source voltage of the MOSFET was not compatible with the oscilloscope that were used to check the output voltage. This caused the output voltage to be limited at 7V, which was lower than the expected output voltage of 10V. So in order to fix this problem, the team decided to use a MOSFET Switch Driver, a High-Side P-Channel Drive and a Low Side N-Channel Drive.

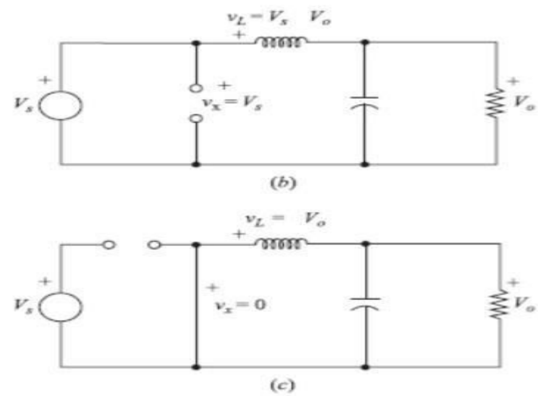


Fig.3.1 Buck Converter with switch On and Off

A High-Side Switch is controlled by an external signal and it connects or disconnects the power source to the load and it source the current to the load. As for a Low-Side Switch, it connects or disconnects the load to the ground and it sinks the current from the load [12]. The 23 connection is a slight modification of a Half-Bridge circuit, which is a High-Side P-Channel MOSFET and a Low-Side N-Channel MOSFET tied with common drain, refer to the figure below.

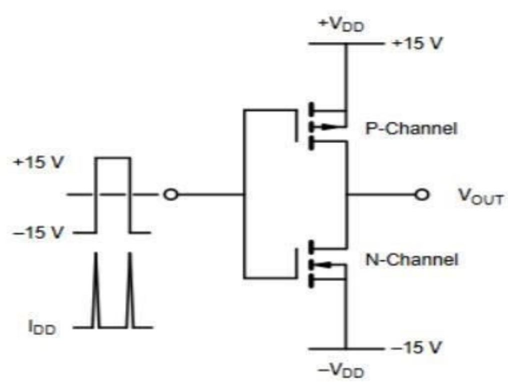
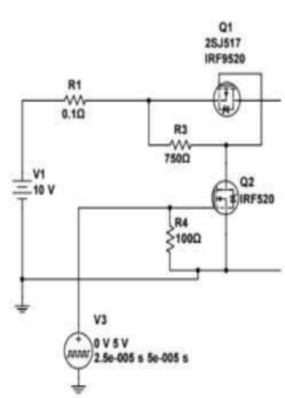


Fig.3.2 A High Side P-Channel and Low-Side N-Channel MOSFET

The figure below shows the modified circuit of the Half-Bridge. The gate of the P-Channel,



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IRF9520, is connected to the drain of the N-Channel MOSFET. Similarly to the figure above, the figure below has PWM input into the gate of the N-Channel and the drain is sourced from the P-Channel MOSFET.

Fig.3.3 The modified of High-Side and Low-Side MOSFET Switch

4. Voltage Divider

When trying to read the output voltage of the buck converter, there was a problem that the team encountered. The Arduino Mega 2560 was the chosen component to perform the power calculation and the MPPT algorithm. The analog pins of the Arduino can only read the voltage from a range of 0-5V. However, the requirement for the prototype is to be able to read the voltage with a range of 0-25V. Therefore, to solve this problem, the team decided to use voltage divider to change the voltage going into the input pin of the Arduino to no larger than 5V. The reduced voltage will get converted back to its original value based on the voltage divider ratio before the Arduino uses that value to compute the power.

5. IGBT (Insulated Gate Bipolar Transistor)

The Insulated Gate Bipolar Transistor (IGBT) is a minority-carrier device with high input impedance and large bipolar current-carrying capability. Many designers view IGBT as a device with MOS input characteristics and bipolar output characteristic that is a voltage controlled bipolar device. To make use of the advantages of both Power MOSFET and BJT, the IGBT has been introduced. It's a functional integration of Power MOSFET and BJT devices in monolithic form. It combines the best attributes of both to achieve optimal device characteristics.

The IGBT is suitable for many applications in power electronics, especially in Pulse Width Modulated (PWM) servo and three-phase drives requiring high dynamic range control and low noise. It also can be used in Uninterruptible Power Supplies (UPS), Switched-Mode Power Supplies (SMPS), and other power circuits requiring high switch repetition rates. IGBT improves dynamic performance and efficiency and reduced the level of audible noise. It is equally suitable in resonant-mode converter circuits. Optimized IGBT is available for both low conduction loss and low switching loss.

6. Soft Switching Transition Techniques

For understanding the process of our proposed design, we need to know what it means for our system to undergo soft switching procedure at the switch and how it helps improve our circuit in general. In a converter and at the switch when performing high frequency operation, we could use a hard switching method which has the following limitations such as causing switching losses, stresses on the circuits components, electromagnetic interference which comes due to high change current and voltage with time and also energy losses across the system at inductors and capacitors.

The solution to overcome this issue is by a soft switching technique at our switches. This can be done in two different methods namely the zero-voltage switching (ZVS) which have been mentioned previously and the zero current switching (ZCS) method. When the switch goes through hard switching it experiences a waveform as seen below

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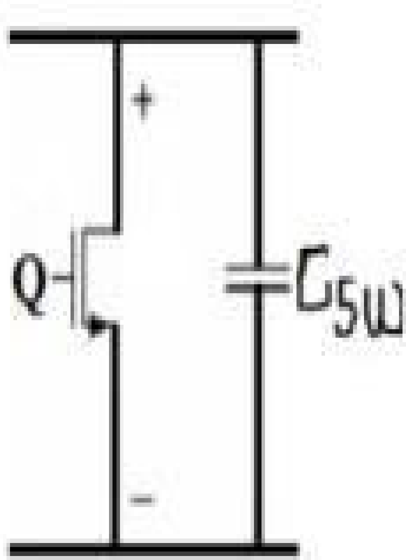


Fig.3.6 Example of ZVS at MOSFET Switch

And from the above diagram we can see that we experience losses both at turn on and turn off which affects the systems efficiency by reducing it. So applying soft switching techniques eliminates these losses either at turn on or turns off depending on the method introduced. We look at the two soft switching techniques that helps improve our system. But we only applied ZVS for improving our system. We would start by discussing what it means to achieve ZVS at the switch. The zero-voltage switching (ZVS), here when this is applied to the switch the main aim is to bring the switch voltage to zero at turn on before applying the gate voltage which causes ideal and zero loss transition and reduced loss at turn off of the switch and we do this by applying a capacitor in parallel to the switch. The capacitor is used as a loss less snubber and this technique is what we used in our new proposed SEPIC converter in both switching devices. We can see these designs below.

IV PRICICIPLE OF WORKING AND OPERATION

1. Circuit Operation

Single-Ended Primary Inductor Converter (SEPIC) is a type of DC-DC converter, that allows the voltage at its output to be more than, less than, or equal to that at its input. The output voltage of the SEPIC is controlled by the duty cycle of the MOSFET. A SEPIC is similar to a traditional Buck Boost converter, but has advantages of having non-inverted output, by means of coupling energy from the input to the output is via a series Capacitor. When the switch is turned off output voltage drops to 0 V. SEPIC is useful in applications like battery charging where voltage can be above and below that of the regulator output.

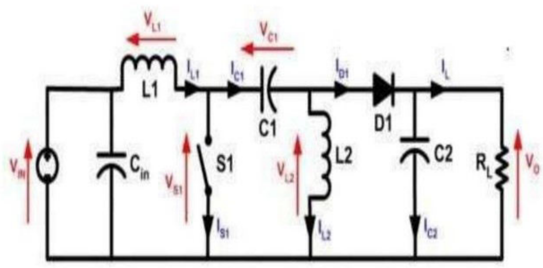


Fig.4.1 Sepic Converter

(a) When Switch is ON:

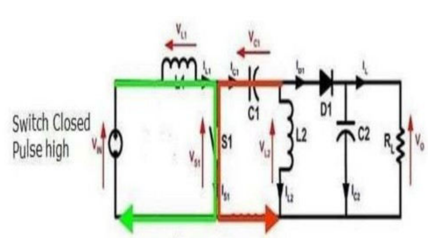
A SEPIC is said to be in continuous-conduction mode if the current through the Inductor (L1) never go down to zero. During a SEPIC's steady-state operation, the average voltage across Capacitor (C1) is equal to the input voltage (Vin). Because Capacitor (C1) blocks direct current, the average current across it (IC1) is zero, making Inductor (L2) the only source of load current. Hence the average current through Inductor L2 is the same as the average load current and hence independent of the input voltage (Vin) Looking at average voltages, the following can be written:

Vin=VL1+Vc1+VL2………. (1)

Because the average voltage of Vcs is equal to VIN

VL1 = −VL2………… (2)

For this reason, the two Inductors can be wound on the same core. Since the voltages are the equal in magnitude, their mutual inductance effect will be zero. Here it is assumed that the polarity of the coil is correct. As the voltages are the equal in magnitude, the ripple currents of the two inductors will be



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equal in magnitude. The average currents can be summed as follows

$$ID1 = IL1 - IL2 \ldots\ldots. (3)$$

When switch (S1) is turned on, current (IL1) increases and the current (IL2) increases in the negative direction. The energy to increasethe current (IL2) comes from the input source. Fig.4.2 SEPIC On State

Since Switch (S1) is a short while closed, and the instantaneous voltage (VC1) is approximately equal to input voltage (VIN), the VL2 is approximately –VIN.

Therefore, the Capacitor (C1) supplies the energy to increase the magnitude of the current in IL2 and thus increase the energy stored in Inductor (L2).

(b) When Switch is OFF

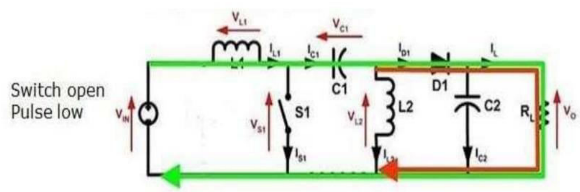

Fig.4.3 SEPIC Off (Continuous conduction mode)

When switch (S1) is turned off, the current (IC1) becomes the same as the current (IL1), as the Inductors will not allow instantaneous changes in current. Current (IL2) will continue in the negative direction, in fact it never reverse direction. It can be seen from the diagram that a negative IL2 will add to the IL1 to increase the current delivered to the load. By Using Kirchhoff's Current Law

$$ID1 = IC1 - IL2 \ldots\ldots..(4)$$

So while Switch (S1) is off, power is delivered to the load from both Inductors L2 and L1. Coupling Capacitor (C1) is charged by Inductor (L1) during this off cycle, and will recharge Inductor (L2) during the on cycle.

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 (VS1) that is higher than Input voltage (VIN).

Its magnitude is determined by the duty cycle of the switch (S1) Since the average voltage across Capacitor (C1) is Input voltage (VIN), the output voltage (VO) is

$$VO=VS1- VIN \ldots\ldots..(5)$$

If VS1 is less than double of VIN, then the output voltage will be less than the input voltage. If VS1 will be greater than double of VIN, then the output voltage will be greater than the input voltage.

2. Duty Cycle Calculations

The amount that the SEPIC converters step up or down the voltage, depends primarily on the duty cycle and the parasitic elements in the circuit. The output of an ideal SEPIC converter is

$$Vo =(D*Vi/1-D)\ldots\ldots..(6)$$

Suppose

D = 0.2, then output is 0.25Vi

D = 0.5, then output is Vi

D = 0.8, then output is 4Vi

However, this does not account for losses due to parasitic elements such as the Diode drop Vd.

This makes the equation

$$VO+Vd=(D*Vi/1-)\ldots\ldots(7)$$

This becomes

$$D =(Vo+Vd/Vi+Vo+Vd)\ldots\ldots..(8)$$

The minimum Duty cycle will occur when the input voltage is at the maximum.

The amount that the SEPIC converters step up or down the voltage depends primarily on the duty cycle and the parasitic elements in the circuit. The output of an ideal SEPIC converter is

$$Vo = (D/1- D)*Vi \ldots\ldots\ldots(6)$$

Suppose D=0.2, then output is 0.25Vi

D=0.5,then output is V_i

D=0.8,then output is $4V_i$

However, this does not account for losses due to parasitic elements such as the diode drop V_d.

3. Operation Models

We would look at a SEPIC converter both as an open loop converter and as a closed loop converter with a controller present. The SEPIC converter either operates in a CCM (continuous conduction mode) or in DCM (discontinuous conduction mode).

Basically, here we would look at the operation mode of the circuit as an open loop SEPIC in continuous conduction mode and then as a closed loop also in CCM. First,

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describing CCM and DCM operation modes briefly before diving deeper into the CCM operation mode of the open loop and closed loop SEPIC converter.

3.1 CCM (Continuous Conduction Mode)

In this case, it defines a SEPIC converter to be operating under CCM when the current through the first inductor labelled L1 never goes down to zero. There it is always conducting all through the circuits run time.

3.2 DCM (Discontinuous continuous Mode)

In this case a SEPIC converter is branded as being in DCM when the current passing through the second inductor named L2 as seen in the figure four is all is allowed to go to zero at a point.

So narrowing it down in the design, modelling and analysis and assuming the following conditions

- Low ripple on capacitors
- The diode is assumed to have a zero diode voltage
- Low parasitic resistance
- And it is functioned in CCM

The basic SEPIC circuit as seen in figure four consists of input voltage (Vin), input inductor (L1), Coupling capacitor (CS), Diode (D1), output Capacitor (CO), input capacitor (Cin), input parasitic resistance (r1), Load (RL), (L2) connected between D1 and CS.

Don= ton/T and Doff= toff/T

Where T is the period, toff and ton is the off and on time of switch. And a MOSFET switch (S1) with duty cycle (D)is used. According to the assumptions of CCM the circuit both in the off and on state of the switch is drawn below and it operation mode explained. Note that there are two methods of analysis, namely the circuit averaging method and the state space averaging method and would look at both methods of analyzing the operation modes of the SEPIC converter and the new proposed SEPIC converter.

V SPECIFICATIONS & DESIGN OF THE PROPOSED TOPOLOGY

1. INDUCTOR CALCULATION

In theory, the larger the Inductors are the better the circuit will operate and reduce the ripple. However, larger Inductors are more expensive and have a larger internal Resistance. This greater internal Resistance make the converter less efficient. Creating the best converter requires choosing Inductors that are just large enough to keep the voltage and current ripple at an acceptable amount.

L =(Vi(Min)+Dmax/ Δio(max)∗fsw……(1)

Where

Vi (Min) = Minimum input voltage

Dmax = Maximum Duty cycle

Δio(max) = Maximum ripple current fsw = Switching frequency

Inductor Current Ripple

The inductor ripple is the ripple current flowing through the inductor when it is ON/OFF, it is given the slope of the inductor current across the inductor is considered as inductor ripple

Voltage across inductor when switch is open =V0

Slope of inductor current =dIL/dt=V0/L

Inductor ripple (ΔI) =V0 (1-D) T/L

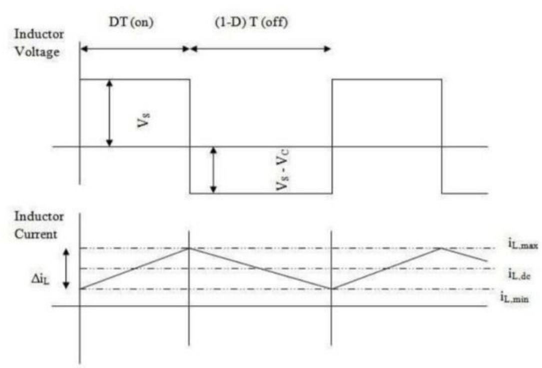

Fig.5.1 Inductor Current Ripple

2. Coupling Capacitor Calculation

A Capacitor is formed from two conducting plates separated by a thin insulating layer. If a current (I) flows, positive charge q, will accumulate on the upper plate. To preserve charge neutrality, a balancing negative charge will be present on the lower plate. There will be a potential energy difference (or voltage) between the plates proportional to q.

v =(d/A€)q…………..(2)

where

A = Area of the plates.

d = Distance of separation of the plates.

€ = Permittivity of the insulating la

q = Charge

The quantity C =(A€/d) is the capacitance and is measured in Farads (F),

hence, q=CV

The current, i, is the rate of charge flow, hence the capacitor equation is

i =(dq/dt)= C (dv/dt)………(3)

The selection of coupling Capacitor Cs depends on the RMS current and is given by

Ics(rms)=Iout*√(Vout+Vd/Vin(Min))……… (4)

The coupling Capacitor must be rated for a large RMS current relative to output power. This property makes the SEPIC much better suited to lower power application, here the RMS current through the Capacitor is relatively small. The voltage rating of it must be greater than the maximum input voltage.

Electrolytic capacitor work well for through whole application, where the size is not limited and they can accommodate the required RMS current rating. The peak to peak ripple voltage on coupling Capacitor (Cs) is

ΔVs=(Iout*Dmax/Cs*Fsw)………(5)

Where

I_{Out} = Output current.

D_{Max}= Maximum Duty cycle.

C_S = Coupling Capacitor Capacitance

$F_{SW=}$Switching frequency

A Capacitor that meets the RMS current requirement would mostly produce small ripple on Cs. Hence the peak voltage is typically close to input voltage.

3. Output Capacitor Calculation

In a SEPIC converter, when the power switch S1 is turned on, the Inductor is charging and the output current is supplied by the output Capacitor as a result Capacitor sees large ripple currents.

Thus the selected output Capacitor must be capable of handling maximum RMS current is

Iout(max)=Iout*√(Vout+Vd/Vin(Min))….. (6)

Where Iout(max) =Iout*

I out(max) = Output current.

V out = Output voltage

Vin (min) = Minimum Input Voltage.

Capacitor Voltage Ripple:

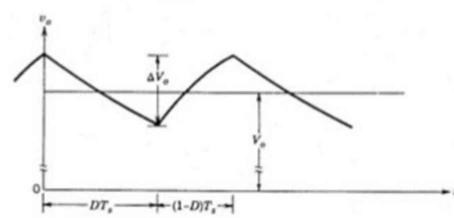

Fig.5.3 Capacitor Voltage Ripple

The ripple in the capacitor is given by the charge acquainted by it for a particular period to the capacitance

Capacitor voltage ripple = Δ Vo ripple =ΔQ*Ts/C

4. Switch Selection:

Here is two switching element in SEPIC. That is Diode and MOSFET. A Metal Oxide Semiconductor Field Effect Transistor (MOSFET) is combination of field effect concept and MOS technology. MOSFET is a type of transistor and used for amplifying or switching electronic signal. MOSFET is voltage-controlled device. The control signals required in MOSFET is lower than the control signal required for BJT. The main advantage of MOSFET over regular transistor is that it requires very little current to turn ON the (<1mA), while delivering much higher current to a load (10to 50A or more).

MOSFETS are two types

1. n-channel enhancement type MOSFET
2. p-channel enhancement type MOSFET

Out of these two, n-channel enhancement MOSFET is more common because of higher mobility of electrons. The main disadvantage of n-channel MOSFET is it provides large on-state resistance. This leads to higher power dissipation. The parameter governing the selection of the MOSFET are:

Minimum threshold voltage = Vth(min)

The on resistance = Rds(on)

Gate drain charge = Qgd

Maximum drain to source voltage = Vds(max)

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The peak switch voltage is equal to = VIN + VOUT
The peak switch current is given by = Iq1(peak)= IL1 +IL2

5. Diode Selection

Diode is an electronic device which has two channels namely n-type and ptype. These two channels are divided by a layer called depletion layer. And this is a one directional device so it conducts only in one direction. Depending on the requirements the diodes are available in many ranges. When diode is in forward bias condition, it act as short circuit as well as when in reverse bias condition, it act as open circuit
The output diode must be selected to handle the peak current and the reverse voltage. In a SEPIC, the diode peak current is the same as the switch peak current IQ1 peak. The minimum peak reverse voltage the diode should withstand is

Vd1 = Vin (max) + V out(max)………(7)

power dissipation in diode is equal to the output current multiplied by the forward voltage drop of the diode. Scotty diode is used to minimize the switching loss.

VI DESIGN, SIMULATION AND RESULTS

Simulation Model:

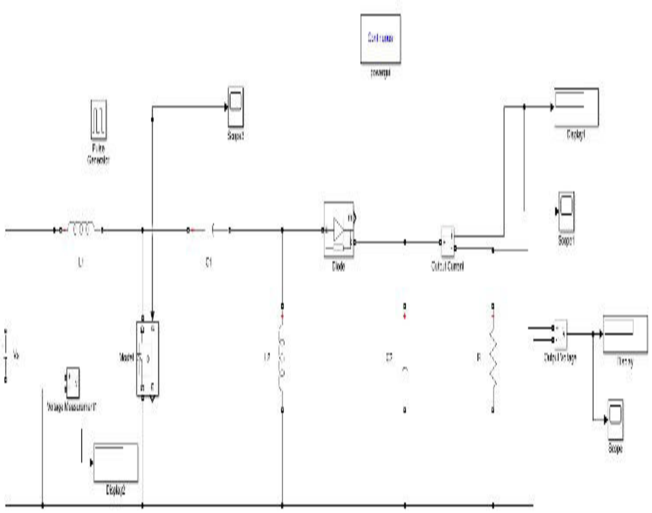

Fig 6.1 Simulation Model

Case-1

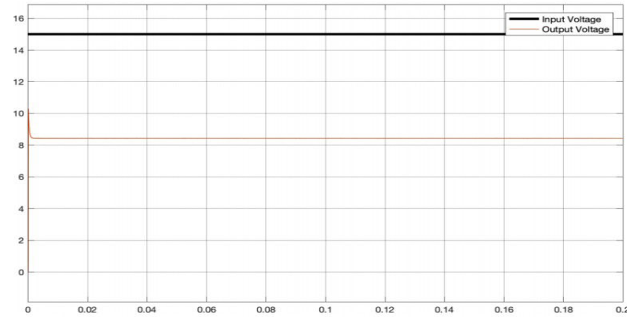

Fig 6.2 Step Down Condition

Case-2

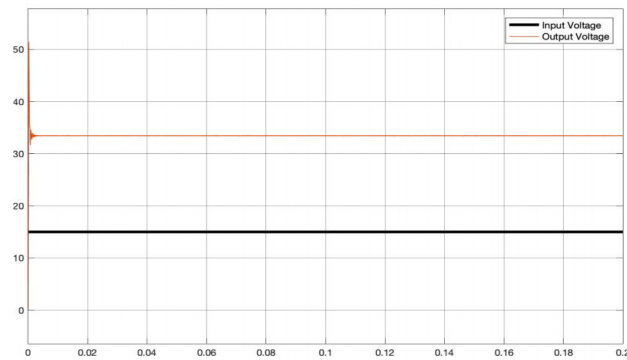

Fig 6.3 Step Up Condition

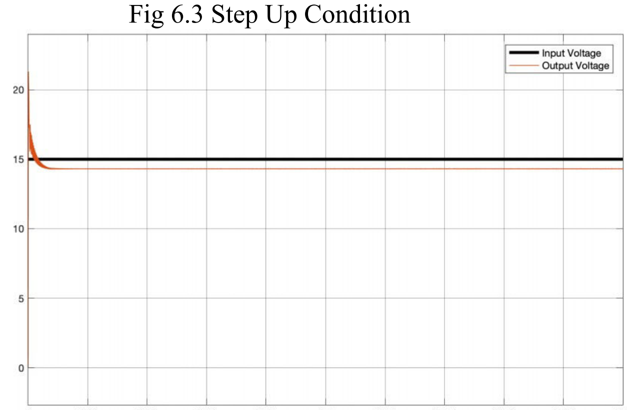

Fig 6.4 Input And Output Voltages are Equal

CONCLUSION

So from the results and analysis you can see that a SEPIC converter is a very interesting converter not only for the fact that it is very efficient but the working process of it is quite fun. It was fun researching about it and it does have a lot of advantages, it is a very good converter when it comes to regulation of voltage even without the upgrades made to it you can see that it has an efficiency of above 90 percent when the parameters are properly selected. You can see that it also maintains the

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polarity at the input hence making it more preferable for use than the popularly known buck-boost converter.

In this work I did make further advancements to the basic SEPIC converter topology by adding resonating capacitors across the diode and the MOSFET switch which are the switching devices to achieve soft switching in the circuit by bringing the voltage down to zero at turn on before the gate voltage is applied causing a reduction in transition loss and you can clearly see the influence on it by the increase in efficiency of the newly proposed SEPIC converter. So bypassed a lot of faults and reduced losses across the switch. Put into consideration also the effect of a controller applied across the basic SEPIC converter we can see by applying feedback and controlling the output you have an efficiency that is close to perfect which also got perfected more by introducing the resonant capacitors into the closed loop basic SEPIC converter.

Generally satisfied with the output results and can say that the whole system was greatly improved my introducing these techniques. Let's take into consideration that even in the closed loop control of the conventional SEPIC converter there was still a slight over shoot not to talk of the over shoot we see when it is not being controlled but with the introduction of the resonating capacitors we eliminate that rapid over shoot which would protect the circuits components and the whole device from damages. So it can be boldly stated that the new resonant SEPIC converter which achieves soft switching by applying ZVS can operate efficiently over a wide variety of input voltage and also can perform excellently when high frequency operation is involved.

Take into account also the time it takes to get to steady state, when the capacitors are introduced both 61 in open and closed loop of the new SEPIC converter we see that it achieves steady state much faster than when there are no resonant capacitors involved in it. Also you saw examples of it working as buck-boost converter only better because its output gets to maintain the same polarity as its input so this converter can be used for a very large range of operations. The more efficient topology is preferred definitely, because it reduces the chance of components damaging, while running a high frequency operation that provides a beautifully working system with positive output voltage both when controlled with a PI controller and when it is open looped. For future purposes in experimental application you should note that it is wiser to use a coupled inductor instead of separate inductors to reduce cost, the required space on PCB and input ripple current is eliminated also.

The SEPIC converter is used in real life applications like equipment's that require battery, Light emitting diodes lightening devices, Lithium ion (Li-ion) and nickel-metal hydride (NiMH) battery chargers, devices that are hand held and DC supply that have wide range input voltages. Thank You for reading, hope you enjoyed it.

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