STUDY OF SOFT SWITCHING BOOST CONVERTER USING AN AUXILIARY RESONANT CIRCUIT

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A Thesis submitted in partial fulfillment of the requirements for the degree of

Bachelor of Technology in "Electrical Engineering"

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CERTIFICATE

This is to certify that the thesis entitled "**Study of Soft Switching Boost Converter using an Auxiliary Resonant Circuit** ", submitted by **Biswajeet Panda(Roll. No. 108EE004) and Ashirbad Sahoo(Roll. No. 108EE016)** in partial fulfilment of the requirements for the award of **Bachelor of Technology** in **Electrical Engineering** during session 2011-2012 at National Institute of Technology, Rourkela. A bonafide record of research work carried out by them under my supervision and guidance.

The candidates have fulfilled all the prescribed requirements.

The Thesis which is based on candidates' own work, have not submitted elsewhere for a degree/diploma.

In my opinion, the thesis is of standard required for the award of a bachelor of technology degree in Electrical Engineering.

Place: Rourkela

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Biswajeet Panda

Ashirbad Sahoo

B.Tech (Electrical Engineering)

Dedicated to

Our beloved parents

ABSTRACT

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This thesis presents Soft Switching DC-DC boost Converter using an Auxiliary Resonant Circuit. The circuit consists of a general Boost Converter with an additional Auxiliary circuit which has a switch, inductor, capacitor and diode. By using an Auxiliary resonant circuit switching losses of a Boost Converter is reduced. Generally Boost Converter circuits have snubber circuit where switching losses are dissipated in external passive resistors; this is known as hard switching. In the proposed topology the generation of switching losses are avoided by forcing voltage (ZVS) or current (ZCS) to zero during switching. The efficiency is improved due to reduction in switching losses. MATLAB simulations are performed to verify the theoretical analysis.

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ABBREVIATIONS AND ACRONYMS

PVA - Photo Voltaic Array
AC - Alternating Current
DC - Direct Current
SPV - Solar Photo Voltaic
MOSFET - Metal Oxide Semiconductor Field Effect Transistor
SEPIC - Single Ended Primary Inductor Converter
PWM - Pulse Width Modulation
EMI - Electro Magnetic Interference
ZVS - Zero Voltage Switching
ZCS - Zero Current Switching
ZVT - Zero Voltage Transition
ZCT - Zero Current Transition
MATLAB - MATrix LABoratory
IC - Integrated Circuit

CHAPTER **1**

INTRODUCTION

1.1 MOTIVATION:

Boost converter is one of the most important and widely used devices of modern power applications. Till now Boost Converters with snubber circuits are used where switching losses are dissipated in external resistors leading to higher switching losses and low overall efficiency. Modern Boost converters use IGBT switches which have the following properties such as high current and voltage rating, fast switching, low power gate drive. These properties lead to following disadvantages such as at high blocking voltage the switching frequency is reduced to low values and due to high switching speed, the rate of change of current and voltages become high. Boost converter with auxiliary resonant circuit can overcome these problems by either forcing current (ZCS) or voltage (ZVS) or both of them to zero. By adopting this topology the total efficiency of the system is improved. As boost converters are widely used these days therefore large amount of power is saved from wastages.

1.2 LITERATURE SURVEY:

Many previous work has been used to carry out the project which includes notes on converter simulation and design. Reference [1] gives an overview of Soft Switching Boost Converter with auxiliary resonant circuit. In this paper simple auxiliary resonant circuit (SARC) is proposed for soft switching. To reduce the switching losses zero current switching and zero voltage switching are adopted. Reference [2] proposes soft switching boost converter with H-I bridge auxiliary resonant circuit. Compared to conventional hard switching boost converter this circuit has better efficiency of about 96%. The efficiency is improved by reducing switching losses by techniques given in references [1] to [9].

Due to large overlapping area of voltage and current in hard switching the switching losses are more. The switching losses are proportional to switching frequency hence higher switching frequencies are not used. By adopting zero voltage switching (ZVS) and zero current switching (ZCS) switching frequency is increased and switching losses are minimized. References [1] to [5] verify the above concepts. Operations with wide range of load and duty cycle can’t be performed by above techniques hence zero voltage transition and zero current transition techniques are adopted. These are given in [5] to [8]. Zero current transition (ZCT) and Zero voltage transition guarantees soft switching with minimum switching losses.

1.3 THESIS OBJECTIVES:

The following objectives are hopefully to be achieved at the end of the project.

1) To study the different Soft Switching Converter topologies and how the switching losses are minimised in comparison to Hard Switching Converters.
2) To study the proposed Soft switching Boost Converter using Auxiliary resonant circuit and design the parameters of the proposed converter.
3) To simulate the Soft Switching Boost Converter in MATLAB and observe the output current and voltage waveform, the switching current and voltage waveform of main and auxiliary switch and compare with theoretical analysis.
4) To study the comparison between the conventional DC-DC Boost converter and the proposed soft switching DC-DC boost converter using auxiliary resonant circuit in terms of efficiency improvement and switching loss reduction.
5) To study the 250mV input Boost converter for low power application. To simulate it in MATLAB and observe the output current and voltage waveform.

1.4 THESIS ORGANISATION:

The Proposed thesis is divided into five chapters including the introduction chapter. Each chapter is different from the other and has its own unique description for better understanding.

Chapter 2: It describes about the different DC-DC converter topologies. The hard switching converter topologies described in this chapter are Buck converter, Boost converter, Buck-Boost converter, Ćuk Converter, SEPIC converter. The soft switching converter ,its concepts and types which includes zero voltage switching (ZVS) and zero current switching (ZCS).The different soft switching converter topologies.

Chapter 3: It describes the analysis of zero voltage switching (ZVS) Boost converter and its schematic diagram. The theoretical waveforms and mode of operations.

Chapter 4: It contains the MATLAB simulation of the proposed soft switching Boost converter with auxiliary resonant circuit. It shows the zero voltage switching (ZVS) and the zero current switching (ZCS). The required waveforms are obtained and analysed.

Chapter 5: It concludes the work done under this project. The future work that can be done under this project to improve the efficiency further is also discussed. The future work that can be undertaken is discussed.

CHAPTER 2

DC-DC CONVERTER TOPOLOGIES

2.1 INTRODUCTION:

A power electronic system consists of one or more power electronic converters. A power electronic converter is made up of power semiconductor devices controlled by integrated circuits. The switching characteristics of power semiconductor devices permit a power electronic converter to shape the input power of one form of power to the other. The static power converters perform this operation very efficiently. The power electronic converters are classified into six types as under.

i. Diode rectifiers- It converts AC input voltage to fixed DC voltage. The input voltage may be single phase or three phase.

ii. AC-DC converter (Phase controlled Rectifiers)- It converts constant AC voltage to variable DC output voltage. The phase controlled converter may be fed from single phase or three phase source.

iii. DC-DC converters (DC choppers)- A DC chopper converters a fixed D voltage to a variable DC output.

iv. DC-AC converters (Inverter)- An inverter converts fixed DC voltage to variable AC voltage. The output may be variable voltage or variable frequency.

v. AC-AC converters- This converts fixed AC voltage to variable AC output voltage. These are of two types. (1) AC voltage controllers- These converter converts fixed AC voltage directly to a variable AC voltage at same frequency.(2) Cycloconverters- This circuit converters input power at one frequency to output power at a different frequency through one stage conversion.

vi. Static switches- A power semiconductor devices can operate as switches or contactors. It possesses many advantages over mechanical and electromechanically circuit breakers.

2.2 DC-DC converter (DC chopper)

A chopper circuit is a static device that converters fixed DC to a variable DC output voltage directly.

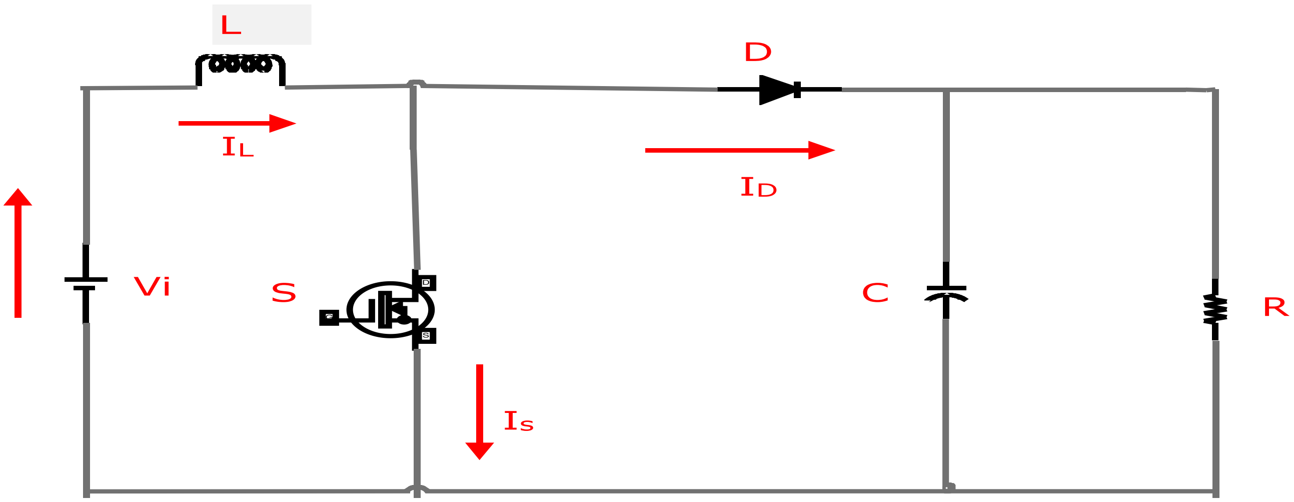

Fig. 2.1- Elementary Chopper Circuit

A chopper is a DC equivalent of an AC transformer since they behave in an identical manner. As chopper involve one step conversion, these are more efficient. The power semiconductor devices used for a chopper circuit can be forced commutated thyristor, power BJT, power MOSFET, GTO or IGBT. These devices can be considered as a switch.

2.3 Principle of chopper circuit-

- Chopper is a high speed on/off semiconductor device.
- It connects and disconnect source to load at a fast speed.
- During the period T_{on} chopper is on and load voltage is equal source voltageV_S.

- During the period T_{off} chopper is off and load current flows through the freewheeling diode D. As a result load terminals are short circuited by D.And load voltage is therefore Zero during T_{off}.

2.4 Output voltage and current waveform

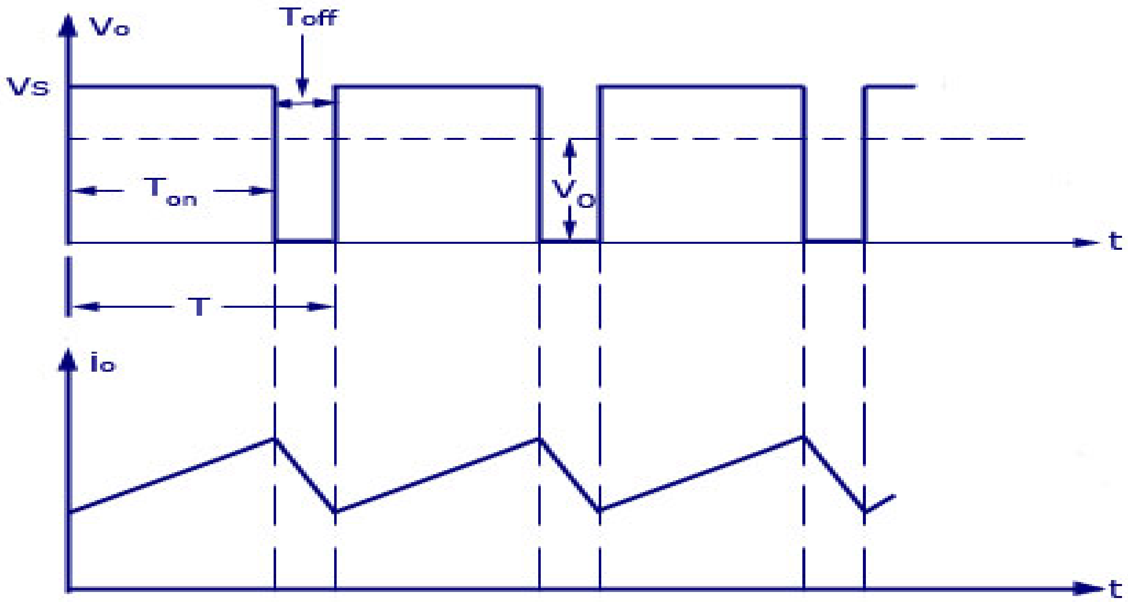

Fig. 2.2 Output Voltage and Current waveform of Chopper Circuit

- V_0=average load voltage
- $V_0 = \frac{T_{on}}{T_{off}+T_{on}} V_s = \frac{T_{on}}{T}$V = K$V_s$
- T=$T_{off} + T_{on}$=Chopping period
- K = $\frac{T_{on}}{T}$ = Duty Cycle
- V_o= f.T_{on}.V_s
- f = $\frac{1}{T}$=Chopping frequency.

Thus the output voltage can be varied by varying the Duty cycle.

2.5 Hard switching Topologies

Converters which are based on traditional switching are known as hard switching converter. During Turn ON period the voltage across the switch tends to increase and the current tends to decrease, which results in some switching losses. Similarly during turn OFF period the voltage tends to increase and the current tends to decrease across the switch. Again it leads to some switching losses.

There are many circuit configurations of these traditional hard switching configurations. They are discussed below.

i. Buck Converter
ii. Boost Converter
iii. Buck – Boost Converter
iv. Ćuk Converter
v. SEPIC Converter

i. Buck Converter

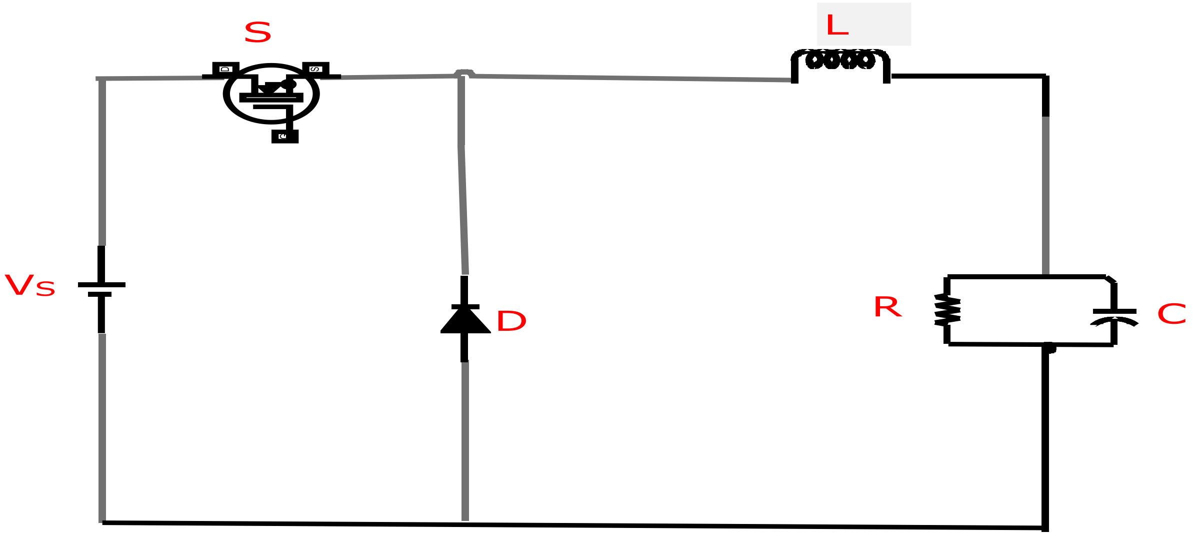

Fig. 2.3 Circuit Diagram of Buck Converter

In Step down converter or Buck converter, the average output voltage Vo is less than the input voltage Vs. when the switch in turned ON, the voltage across the load is Vs. the current flows through the circuit as shown in the figure. When the switch is turned OFF, the current direction is same as before, but the voltage across the load is zero. The power flows from source to load, hence the output voltage is less than the source voltage, which can be determined by the duty cycle of the GATE pulse to the switch. The load current is smoothen by the inductor and the capacitor makes the output voltage ripple free. Hence a constant output voltage is obtained.

ii. Boost Converter

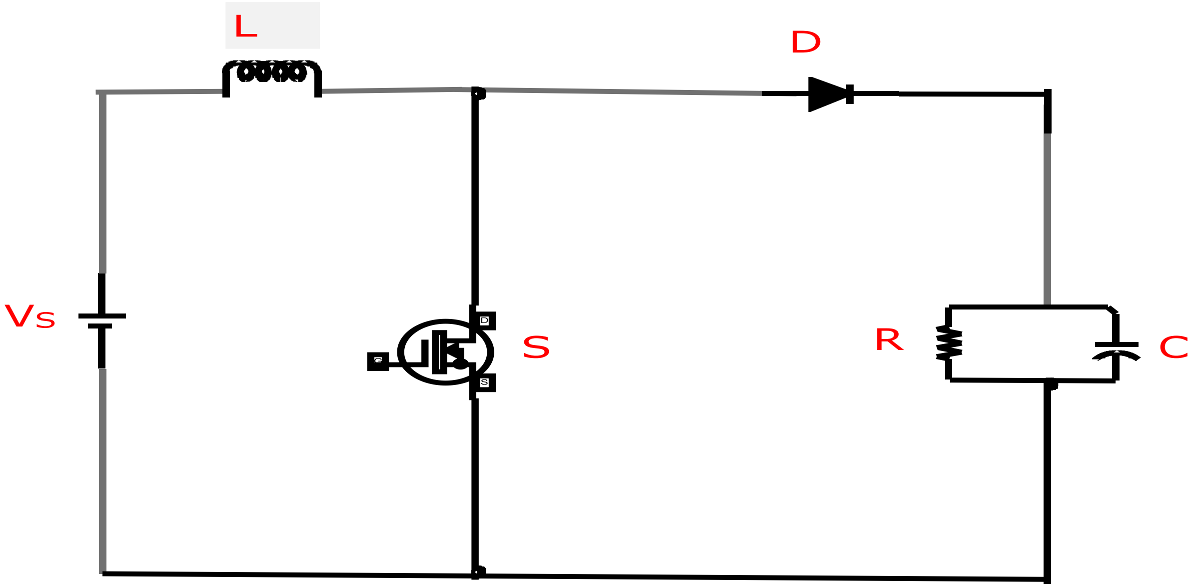

Fig. 2.4 Circuit Diagram of Boost Converter

In step up converter or Boost converter, the average output voltage Vo is more than the input voltage Vs. When the switch is turned ON, current through the inductor increases and the inductor starts to store energy. And when the switch is made OFF, the stored energy in the inductor starts to dissipate. The current is forced to flow through the Diode and load during the turn off time. As a result the voltage across the load exceeds the source voltage.

iii. Buck-Boost Converter

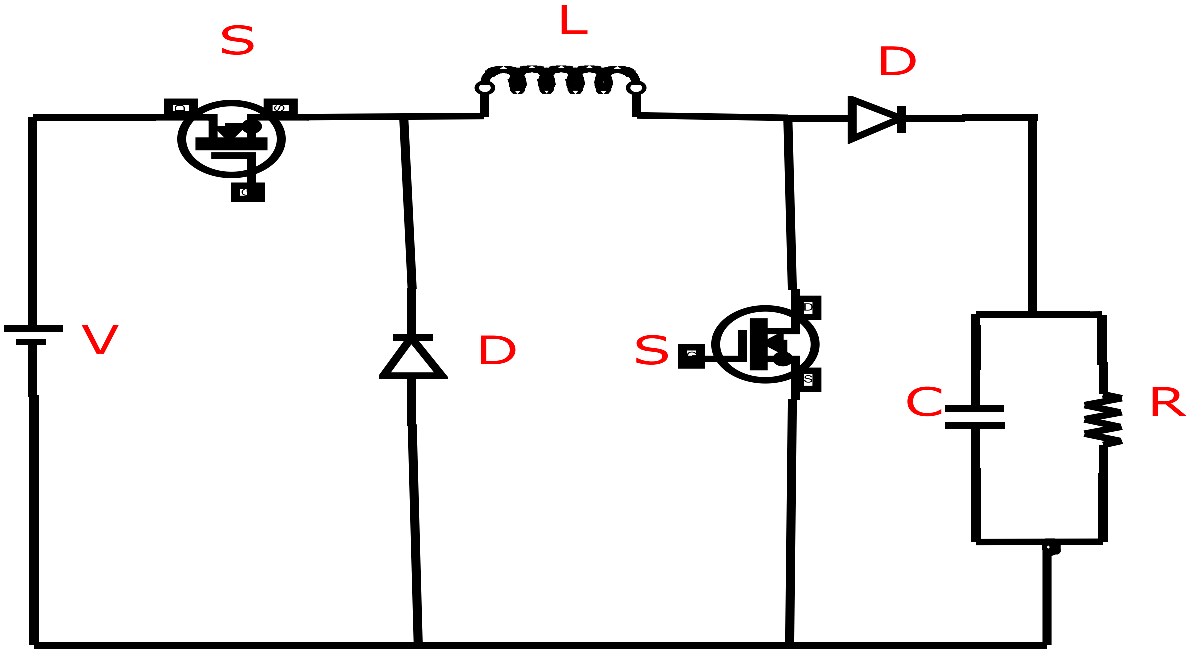

Fig. 2.5 Circuit Diagram of Buck-Boost Converter

In Buck-Boost converter the output voltage can be either greater than or less than the input voltage depending upon the duty cycle. When the switch is turned ON, the inductor starts storing energy, and when the switch is made OFF, the stored energy is supplied to the capacitor and load. So the output voltage can be varied by the duty cycle of the GATE pulse of the switch.

iv. Ćuk Converter:

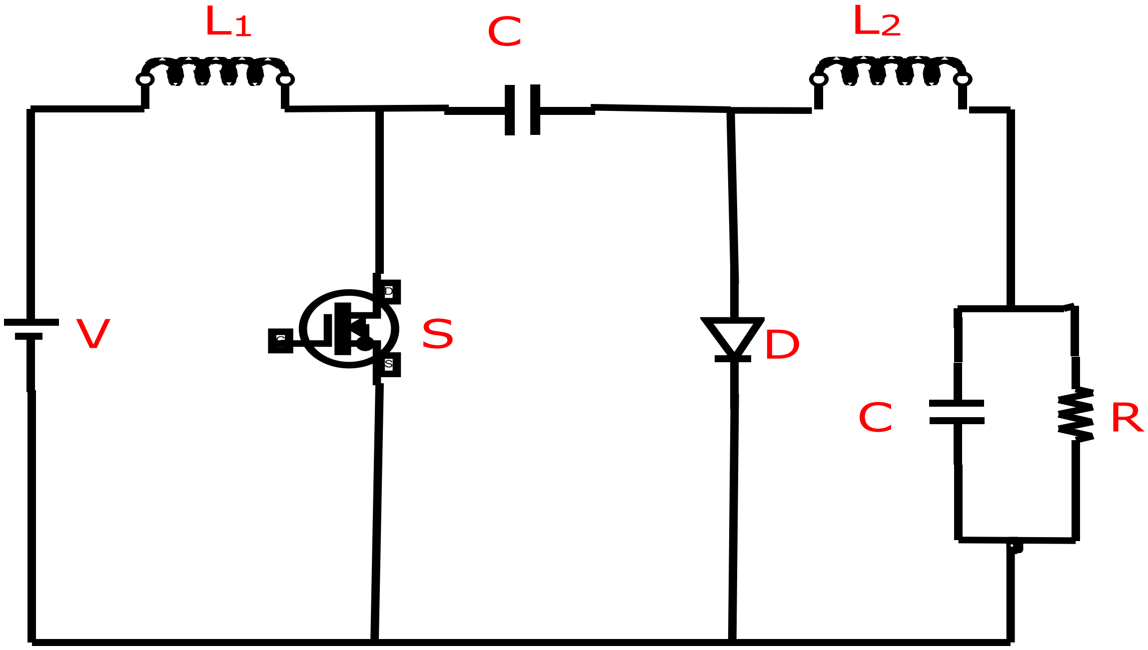

Fig. 2.6 Circuit Diagram of Cuk Converter

This is similar to Buck-Boost converter. But in this case the main energy storing element is capacitor, unlike the inductor in case of Buck-Boost converter. The capacitor is charged during the turn ON period, through the inductor L1 and discharges the stored energy in the turn OFF period through the inductor L2.

v. SEPIC converter:

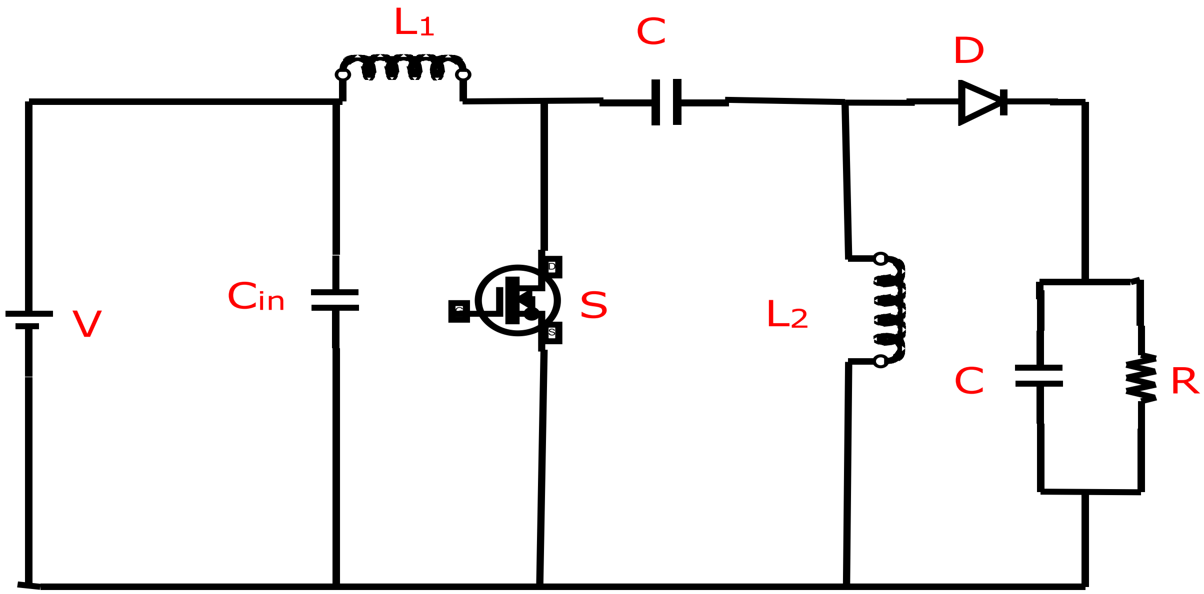

Fig.-2.7 Circuit Diagram of SEPIC Converter

Single Ended Primary Inductor Converter (SEPIC) is a DC – DC converter whose output voltage is greater than, equal to or less than the input voltage. This is similar to Buck-Boost converter with an advantage of generating non-inverting output. Energy is exchanged between the inductor and capacitor to convert one voltage to another. During the turned ON period, the inductor L2 is charged by the capacitor C1. And during turned OFF period, the capacitor is charged by the inductor L1. Hence the power is transferred from inductor L1 and L2 to the load during the OFF time period.

Comparison of the above mentioned hard switching converters are given in the Table 2.1

TABLE 2.1: HARD SWITCHING DC-DC CONVERTER TOPOLOGIES

DC –DC CONVERTER	Number of Switches	Range of Average Output Voltage	Average Output Voltage	Relationship between the duty cycle and Output Voltage
Buck Converter	One	0 - V_i	$D\,Vin$	Linear
Boost Converter	One	V_i -∞	$\frac{D}{1-D}\,Vin$	Non-Linear
Buck-Boost Converter	Two	0 – V_i and V_i - ∞	$-\frac{D}{1-D}\,Vin$	Non- linear
Cuk Converter	One	0 – V_i and V_i - ∞	$-\frac{D}{1-D}\,Vin$	Non- linear
SEPIC Converter	One	0 – V_i and V_i - ∞	$-\frac{D^2}{1-D}\,Vin$	Non- linear

2.6 SOFT SWITCHING TOPOLOGIES:

a. Concept of soft switching:

In the traditional PWM converters operating on hard switching, where the current and voltage pulses goes from high to low value or from low to high value during the transition period, switching loss occurs. Also generate a substantial amount of Electromagnetic interference. These losses arise because of output capacitor of transistor, capacitance of diode and diode reverse recovery. From observation, it is seen that the switching loss is directly proportional to the switching frequency. So the higher switching loss limits the switching frequency to a minimum value. Because of wide spectral range of harmonics present in PWM waveform, a high Electro Magnetic Interference (EMI) occurs. Current spikes caused by Diode recovery can also result in this EMI.

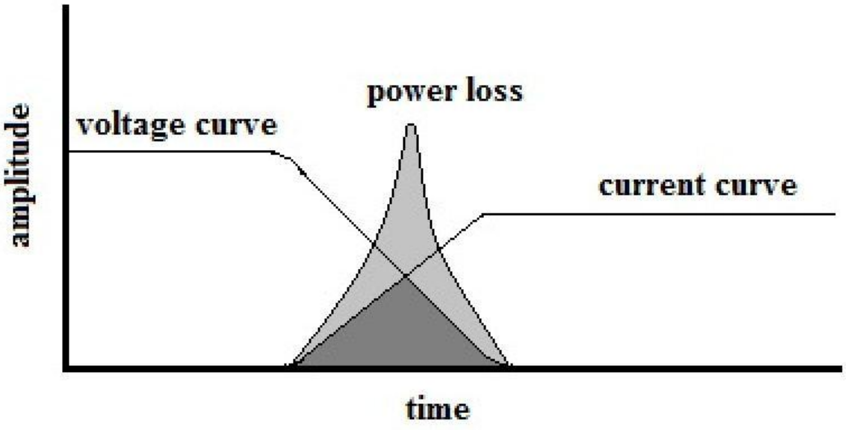

Fig. 2.8 Hard Switching Phenomenon

Soft switching techniques can reduce the switching losses and Electromagnetic interference by putting some stress on the devices. When either current or voltage is zero during the turn ON or turn OFF period, then the product of the voltage and current becomes zero, which leads to zero power loss. Hence the switching loss can be eliminated and the device can operate at high switching frequency. Size and weight of the device is reduced as the heat sink is not required.

Types of soft switching techniques are:

i. Zero voltage switching (ZVS)

ii. Zero current switching (ZCS)

i. Zero voltage switching (ZVS)

In this technique, the switching takes place at zero voltage condition

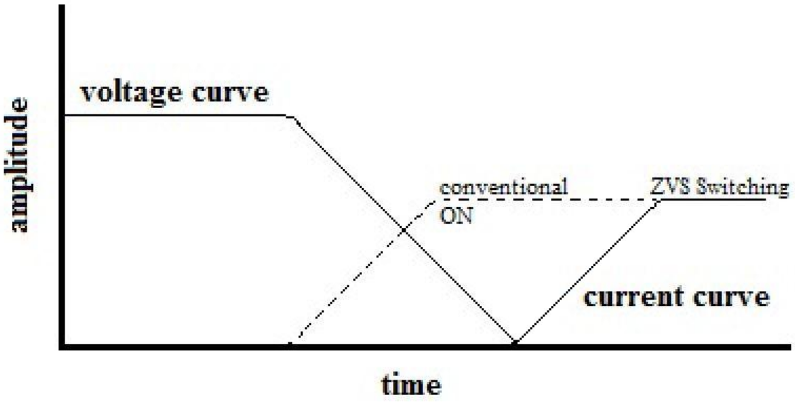

Fig. 2.9 Zero Voltage Switching (ZVS)

ZVS is used during turn ON of the device. Initially the main switch is OFF and the auxiliary switch is ON. So the current through the main switch is zero but the voltage is not zero. During the turn ON, voltage is made zero and current is given some time delay so that the current will begin to rise after the voltage is zero.

ii. Zero current switching (ZCS)

In this technique, the switching takes place at zero current condition.

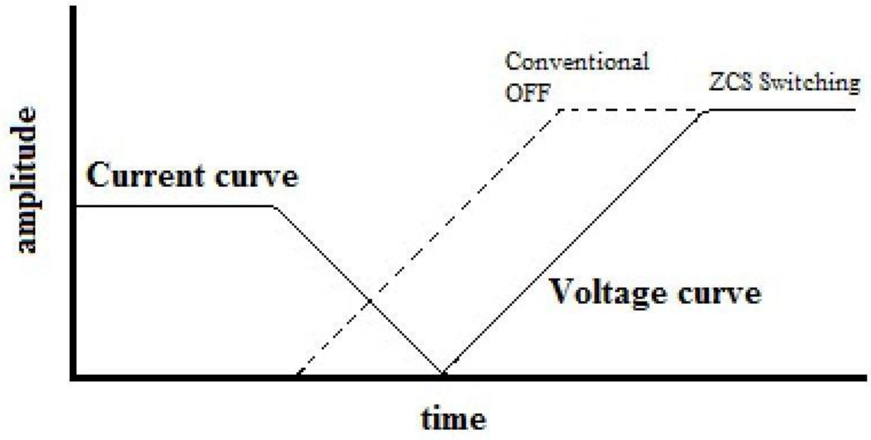

Fig. 2.10 Zero Current Switching (ZCS)

It is used at turning OFF of the device. Initially the device is conducting. So the current through the device is not zero but the voltage across it is zero. In ZCS condition, the current is made to zero and the voltage is allowed to rise after the current becomes zero.

b. Soft switching converter topology:

i. Synchronous Buck Converter:

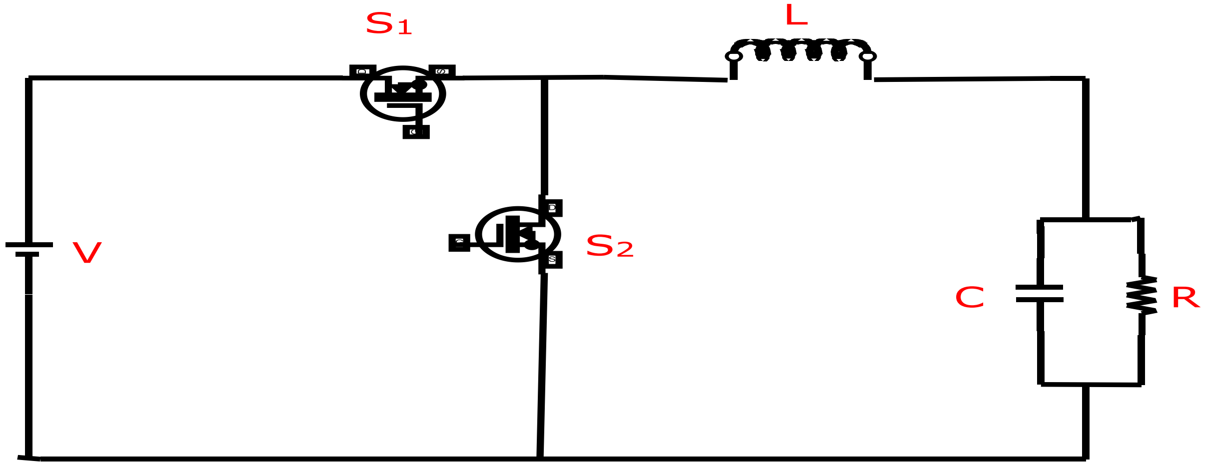

Fig. 2.11 Synchronous Buck Converters

In this converter two synchronised switches are used. To reduce the conduction losses a second switch is used in place of diode. As there is no Auxiliary circuit hence switching losses are not reduced. Hence this can be used only in low switching frequency applications.

ii. Proposed soft switching boost converter with Auxiliary resonant circuit:

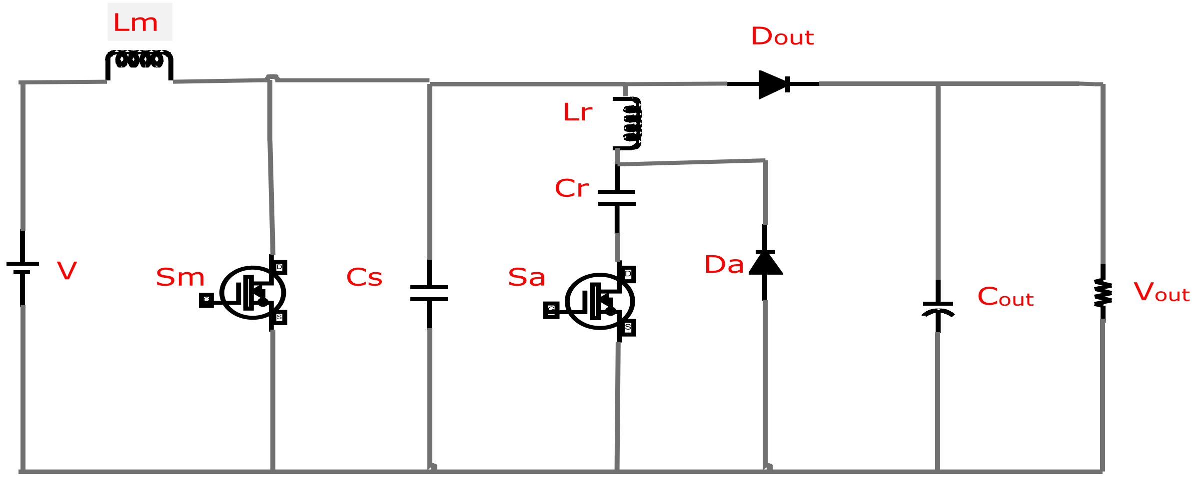

Fig. 2.12 Boost Converter with Auxiliary Resonant Circuit

In the proposed Soft Switching DC-DC boost Converter using an Auxiliary Resonant Circuit. The circuit consists of a general Boost Converter with an additional Auxiliary circuit which has a switch, inductor, capacitor and diode. By using an Auxiliary resonant circuit switching losses of a Boost Converter is reduced. In the proposed topology the generation of switching losses are avoided by forcing voltage (ZVS) or current (ZCS) to zero during switching.

2.7 CONCLUSION

In this chapter different types of hard switching boost converter topologies are studied which include buck converter, boost converter, buck-boost converter, cuk converter, SEPIC converter. Different types of soft switching techniques such as zero voltage switching and zero current switching are studied. Various soft switching converter topologies such as Synchronous buck converter and Boost Converter with auxiliary resonant circuit are studied.

CHAPTER 3

ANALYSIS OF BOOST CONVERTER WITH AUXILIARY RESONANT CIRCUIT

3.1 INTRODUCTION:

Boost converter with auxiliary resonant circuit finds its major use in low power applications as a rectifier because of its high efficiency and low consumption of area. The circuit consists of a general Boost Converter with an additional Auxiliary circuit which has a switch, inductor, capacitor and diode. By using an Auxiliary resonant circuit switching losses of a Boost Converter is reduced. In the proposed topology the generation of switching losses are avoided by forcing voltage (ZVS) or current (ZCS) to zero during switching. The conduction losses can be reduced by replacing the diode with a low resistance path provided by the IGBT. In order to reduce the switching losses, the auxiliary inductor and capacitor operate in resonance with each other, thus giving it the name resonant converter. The soft switching techniques employed for smooth transition of voltage and current through the IGBT are Zero Voltage Switching (ZVS) and Zero Current Switching (ZCS). The switching losses and Electromagnetic Interference (EMI) occurs only during switch on and switch off cases of the Boost converter.

3.2 CIRCUIT DIAGRAM OF BOOST CONVERTER WITH AUXILIARY RESONANT CIRCUIT:

The overall circuit diagram of Boost converter with Auxiliary Resonant Circuit is as shown in the fig.3.1.

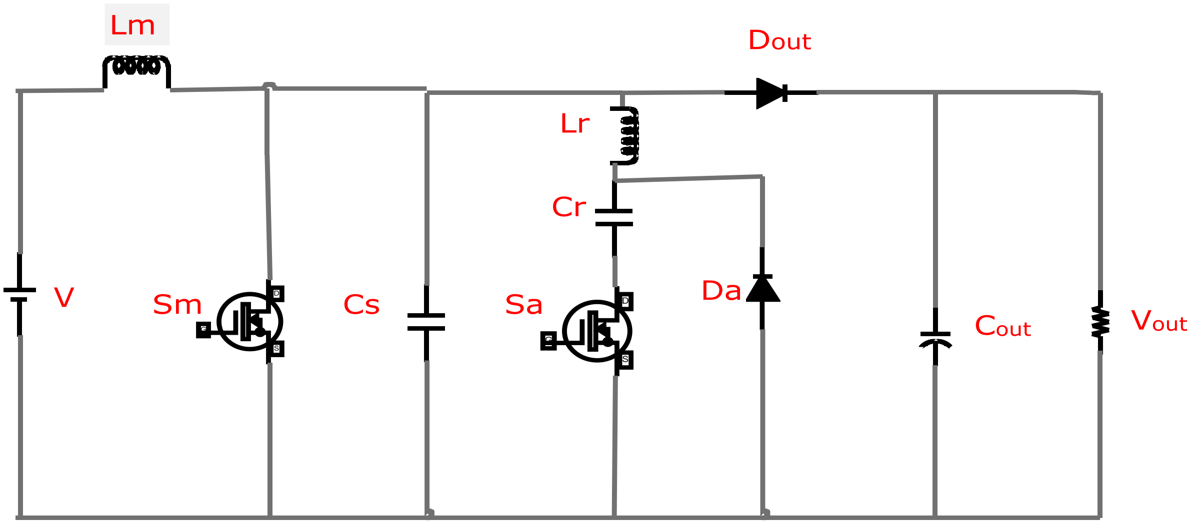

Fig. 3.1 Proposed Boost Converter with Auxiliary Resonant Circuit

The proposed converter consists of 2 IGBTs ‘S_m’, ‘S_a’. IGBT ‘S_m’ is the main IGBT responsible for the output voltage and power. ‘S_a’ is the auxiliary IGBT which is responsible for soft switching of the main IGBT ‘S_m’. ‘S_a’ is the IGBT which replaces the diode in order to provide low resistance path. The output capacitor acts as filter circuit providing only the DC component and filtering the AC component. A resonant inductor ‘L_r’ and a resonant capacitor ‘C_r’ are placed in series with the IGBT S_m. These three together cause the ZVS of the main IGBT ‘S_m’. A Schottky diode is used to discharge the voltage of the resonant capacitor.

3.3 OPERATING MODES AND ANALYSIS:

The operation of the DC - DC Boost converter with auxiliary resonant circuit is explained in 9 modes whose explanations are given below. Each switching cycle is explained in these modes of operation with the help of the typical waveforms and the circuit diagrams for each mode of operation. The characteristics of each parameter and their operation at each mode are explained.

Theoretical waveforms:

Theoretical waveforms include the values of all the parameters such as voltage across and current through the individual switches(S_m and S_a), resonant inductor (L_r) and resonant capacitor (C_r) during a switching cycle consisting of all eight modes of operation.

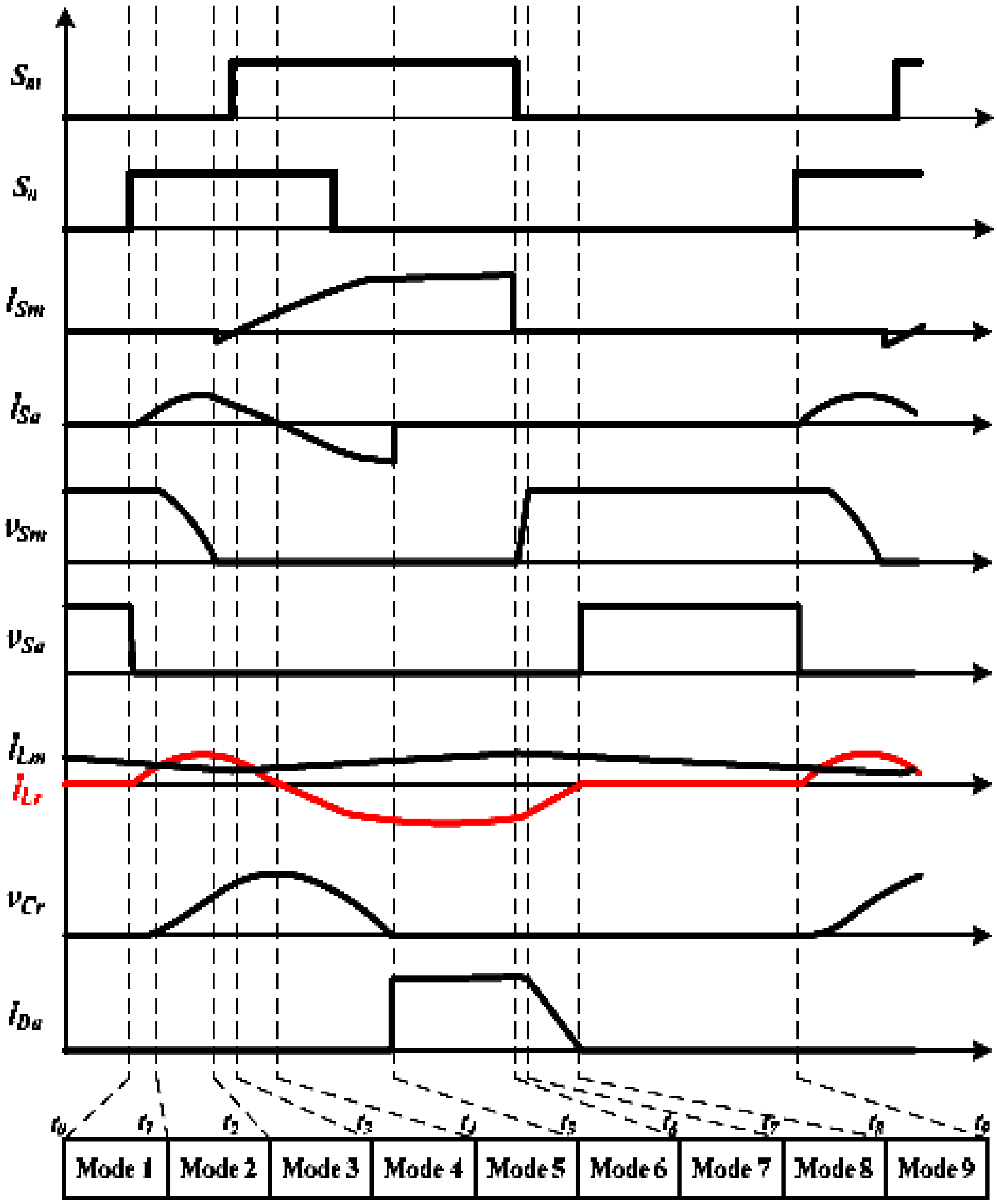

Fig. 3.2: Waveforms of different parameters of Boost Converter with Auxiliary Resonant Circuit.

3.4 MODES OF OPERATION:

MODE 1: (t_0- t_1)

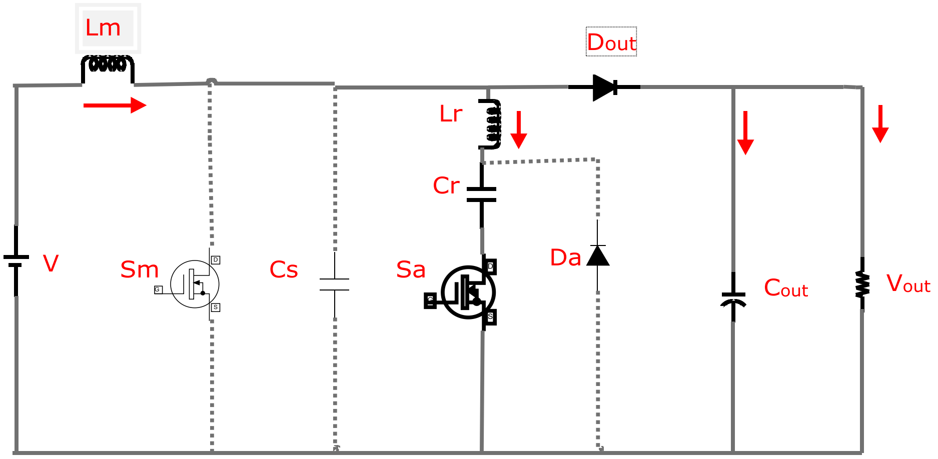

Fig. 3.3: Mode-1

At t_0, the main switch S_m is turned off and auxiliary switch S_a is turned on with zero current switching. When the resonant inductor (L_r) resonates with the resonant capacitor(C_r),a resonant loop of L_m-L_r-C_r-S_a- V_{in} is formed. The resonant capacitor is charged to V_{out}. .If the current of L_m is equal to that of L_r ,mode 1 ends.

MODE 2: (t_1- t_2)

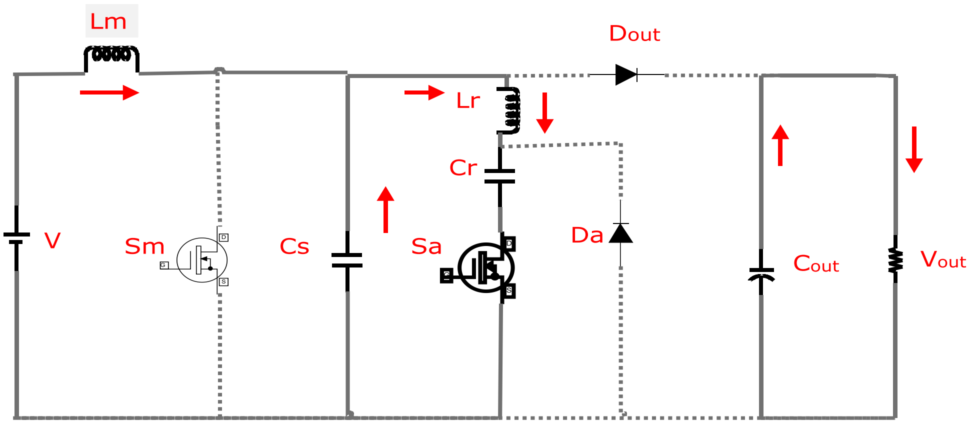

Fig. 3.4: Mode-2

The current through L_r continues to increase due to resonance between L_r and C_r. The charged in the snubber capacitor (C_s) starts to discharge and mode 2 ends when the voltage of Cr is to zero.

MODE 3: (t_2 - t_3)

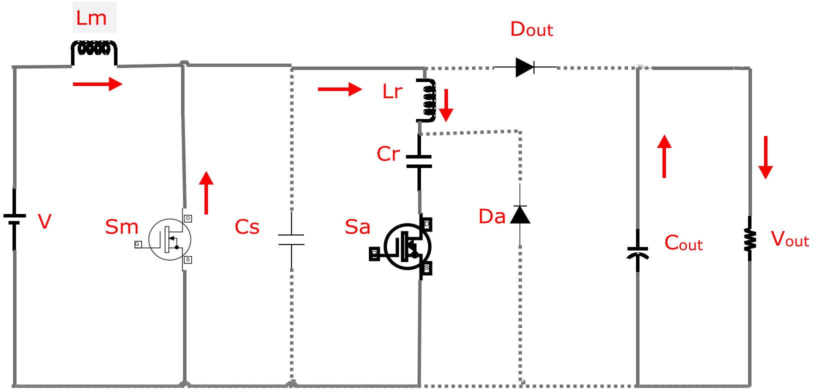

Fig. 3.5: Mode-3

When the anti-parallel Diode S_m is turned ON, it makes voltage across the switch S_m to zero. When the main inductor current becomes equal to the resonant inductor current, this mode ends.

MODE 4: (t_3 - t_4)

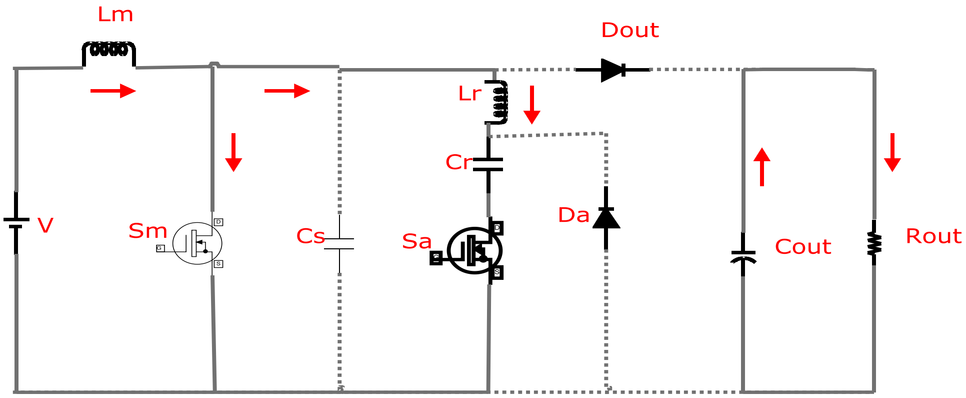

Fig. 3.6: Mode-4

The main switch S_m is turned ON, when the voltage is zero. The resonant circuit is charged continuously through the capacitor.

MODE 5: (t_{4}- t_5)

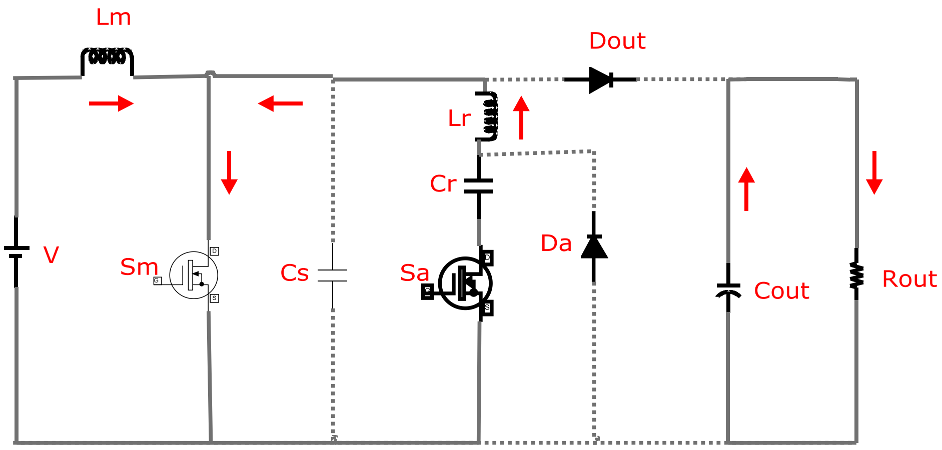

Fig. 3.7: Mode-5

In this mode, the current flows through the anti-parallel Diode of Sa. If the auxiliary switch S_a turns OFF in this interval, then it operate with ZVS. This mode ends when the resonant capacitor C_r discharges fully.

MODE 6: (t_{5}- t_{6})

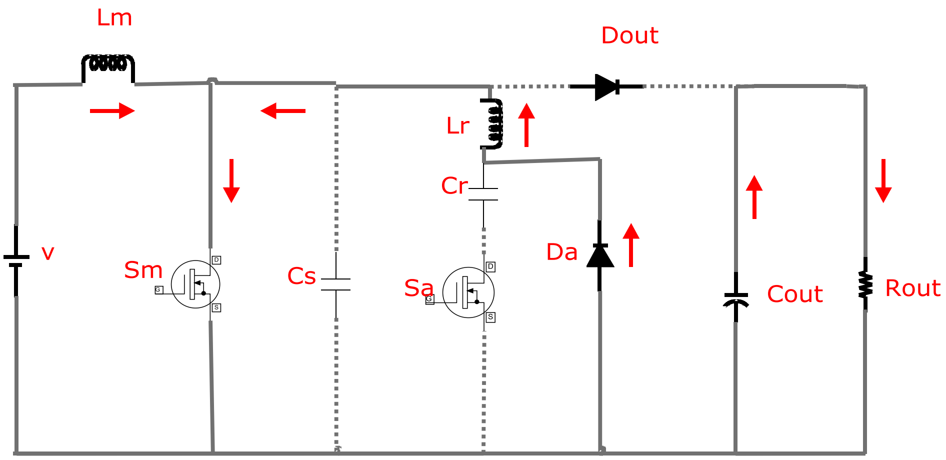

Fig. 3.8: Mode-6

In this mode, the current flows through the auxiliary Diode D_a instead of the anti-parallel diode of the auxiliary switch $S_{a.}$ When S_m is turned OFF, this mode is ended.

MODE 7: (t_{6}- t_{7})

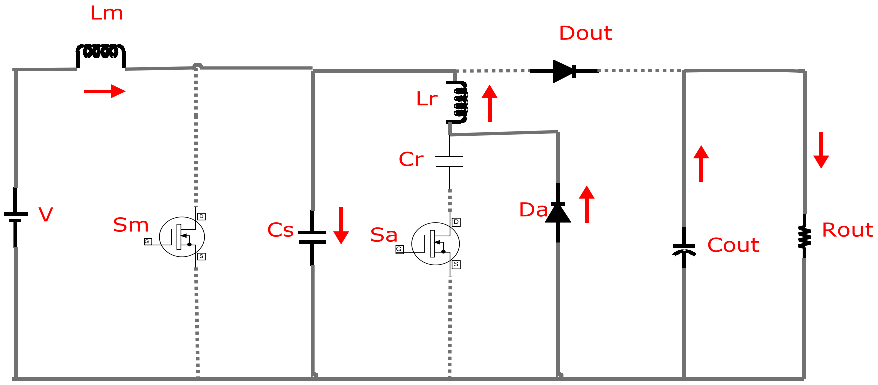

Fig. 3.9: Mode-7

The main switch is turned ON with ZVS by the snubber capacitor. Energy is stored in the snubber capacitor C_s. When the C_s is fully charged, this mode ends.

MODE 8: **(**t_{7-} t_8**)**

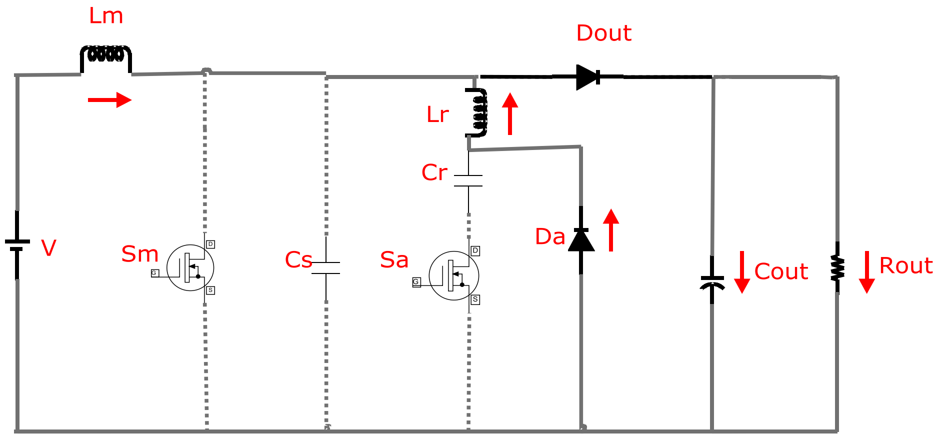

Fig. 3.10: Mode-8

In this mode, the resonant inductor L_r starts discharging the stored energy, which is transferred to the load through the output diode D_{out}. This mode ends when the resonant inductor is fully discharged.

MODE 9: (t_{8}- t_{9})

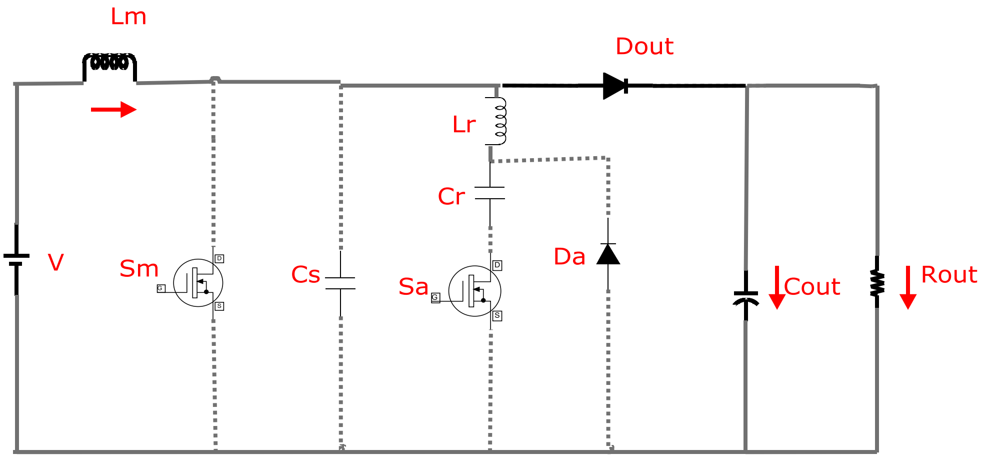

Fig. 3.11 Mode 9

In this mode, all the switches are turned OFF. So the input current flows through the output diode D_{out}. This mode is ended with the turning ON of the auxiliary switch S_a.

3.5 PARAMETER DESIGN

$$D = 1 - \left(\frac{V_{in(min)} * \eta}{V_{out}}\right)$$

D= Duty Cycle

$V_{in(min)}$ = Minimum input Voltage

V_{out}= Desired Output Voltage

η = Efficiency of the converter

$$L = \frac{V_{in}}{\Delta I_L} * (V_{out} - V_{in}) \frac{1}{V_{out}} * \frac{1}{f_s}$$

L= Inductance of main inductor

f_s= Switching Frequency

ΔI_L= estimated inductor ripple current

$$\Delta I_L = (0.2 - 0.4) * I_{out(max)} * \frac{V_{out}}{V_{in}}$$

$I_{out(max)}$= Maximum output current

$$C_{out(min)} = \frac{I_{out(max)}}{f_s} * \frac{D}{\Delta V_{out}}$$

$C_{out(min)}$= Minimum Output Capacitance

$$\Delta V_{out}(ESR) = ESR * (\frac{I_{out(max)}}{1-D} * \frac{\Delta I_L}{2})$$

$\Delta V_{out}(ESR)$= Additional output voltage ripple due to capacitors ESR

ESR= Equivalent series resistance of the output capacitor

The values of parameters calculated using these equations are as follows:

Main Inductor (L) = 160 µH

Snubber Capacitor (C) = 1200 nF

3.5 CONCLUSION

In this chapter Boost Converter with auxiliary resonant circuit is presented. Different modes of operation of the converter are studied. The different parameters of the proposed converter are designed using the given mathematical equations.

CHAPTER **4**

SIMULATION RESULTS AND DISCUSSION

4.1 INTRODUCTION:

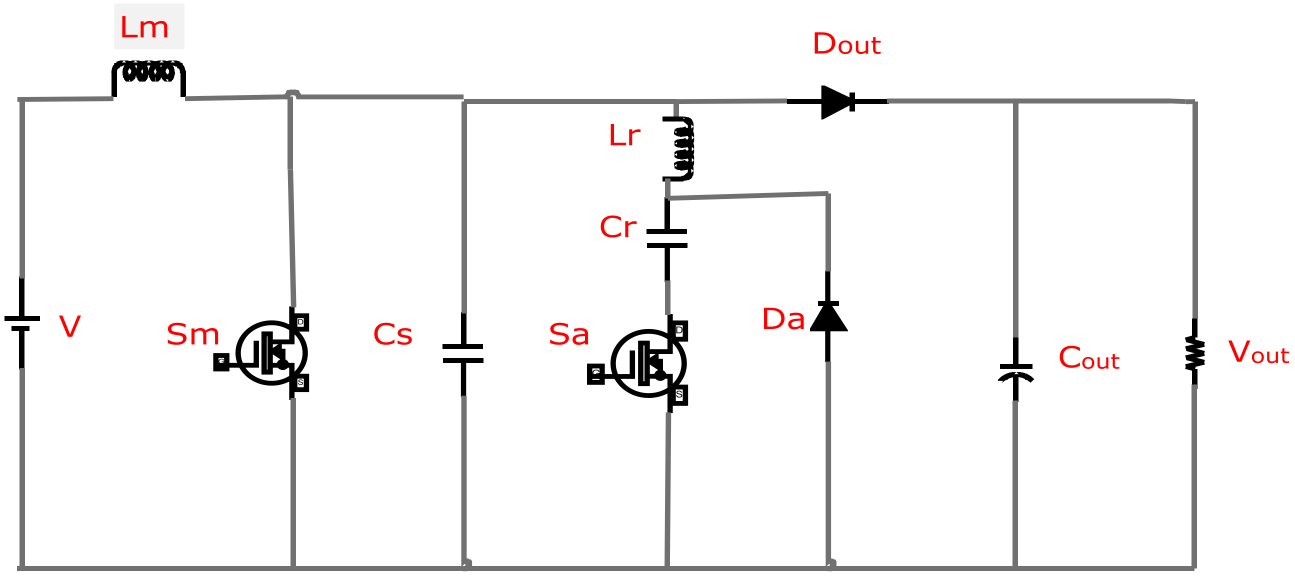

Fig. 4.1: Circuit Diagram of Boost Converter with Auxiliary Resonant Circuit

The above proposed boost converter with auxiliary resonant circuit is simulated in MATLAB-SIMULINK. The values of the circuit parameters are given below:

Input voltage (V_{in}) = 150 V

Switching Frequency (f_{sw}) = 30 KHz

Main Inductor (L_m) = 160 µH

Resonant Inductor (L_r) = 10 µH

Snubber Capacitor (C_s) = 1200 nF

Resonant Capacitor (C_r) = 1000 µF

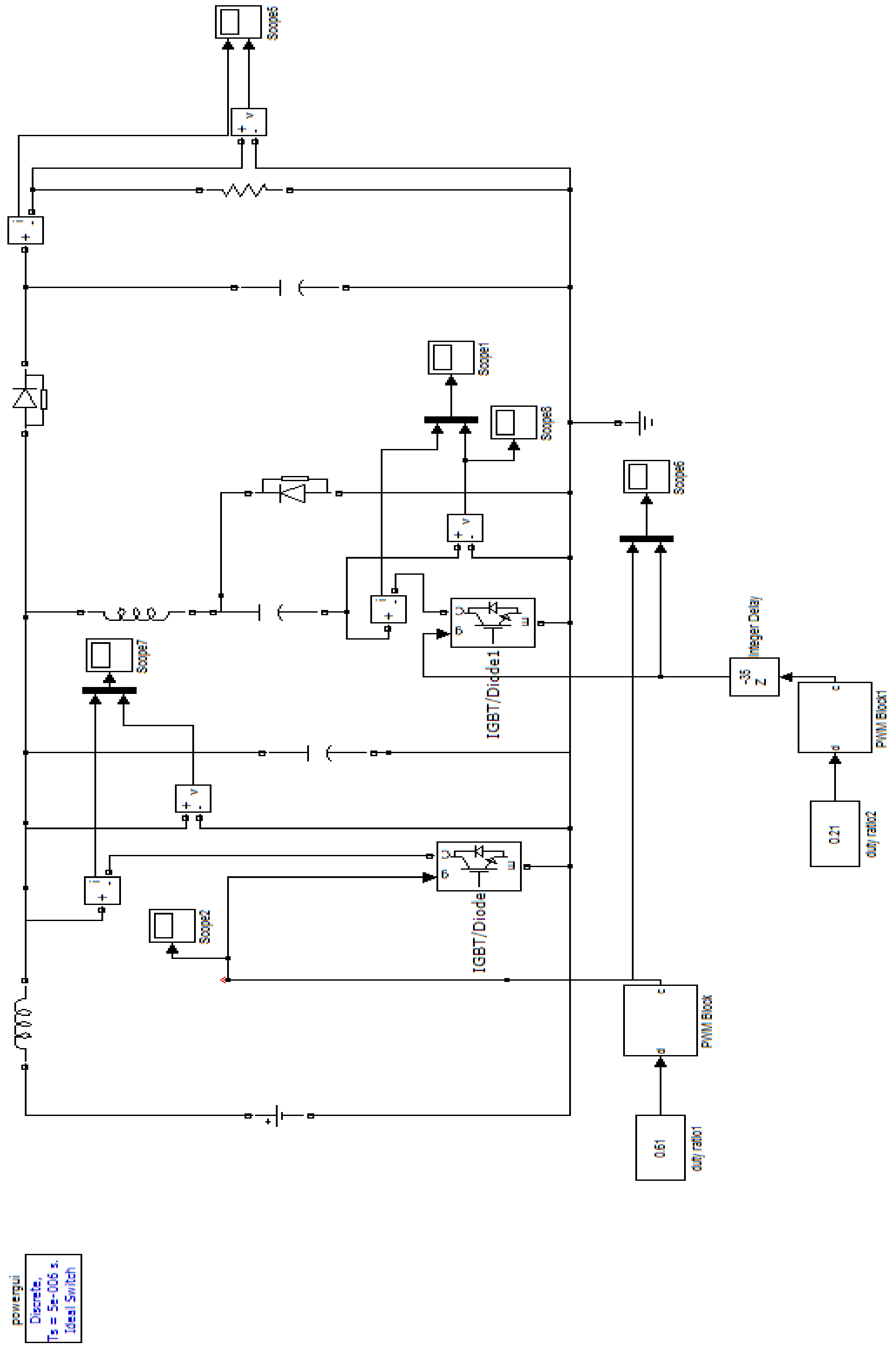

Fig. 4.2: Overall MATLAB-Simulink Model

The proposed Boost Converter has two switches namely main switch and auxiliary switch. The main switch has a duty ratio of 0.61 while that of auxiliary switch is 0.21. The main switch duty ratio determines the average output voltage. The function of auxiliary switch is to enable the main switch to operate soft switching. First the auxiliary switch is turned ON then the main switch in turned ON after some time delay. The resonant loop of the resonant inductor (L_r) and resonant capacitor (C_r) is completed by the turning ON of the auxiliary switch. By the help of resonance the auxiliary switch is made to operate at ZCS. As the snubber capacitor is discharged the current of the resonant loop flows through the anti-parallel diode of the main switch. By turning ON the main switch the ZVS is assured. As the resonant capacitor is fully discharged the auxiliary switch is turned OFF.

The PWM signal of the main switch is given some delay compared to auxiliary switch. The phase difference is obtained by delaying the carrier waveform. The main switch is turned ON while the auxiliary switch is still in the ON state.

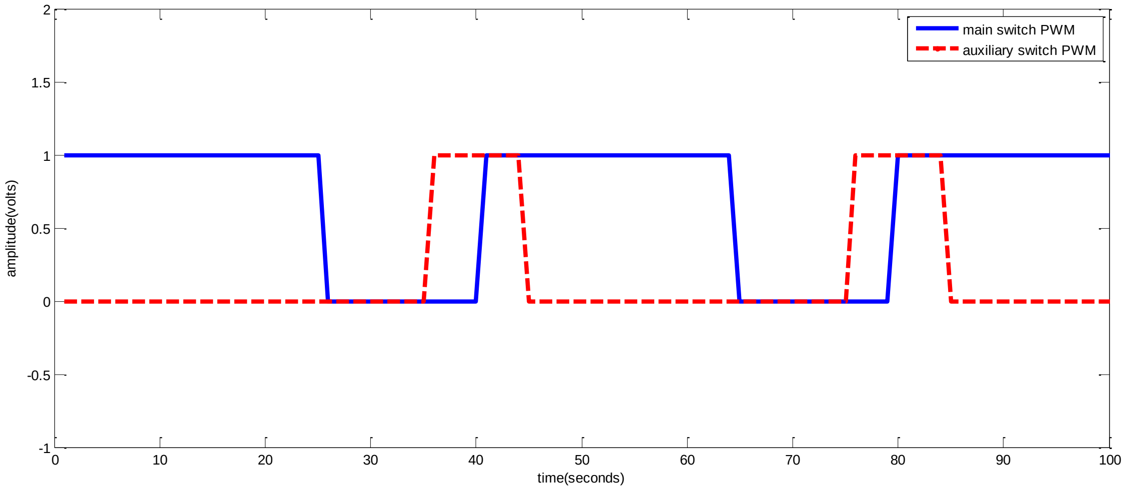

Fig. 4.3: Gate Pulse input to Main Switch and Auxiliary Switch

The carrier waveform used is Saw tooth waveform instead of Triangular waveform. When the reference value is more than the carrier waveform the output PWM signal is HIGH. The switching turn ON points is determined by the saw tooth waveform used.

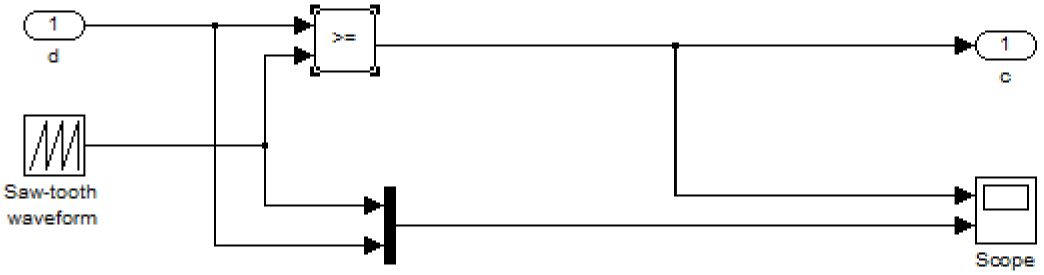

Fig. 4.4: Block Diagram of PWM Generator

4.2 SIMULATION RESULTS:

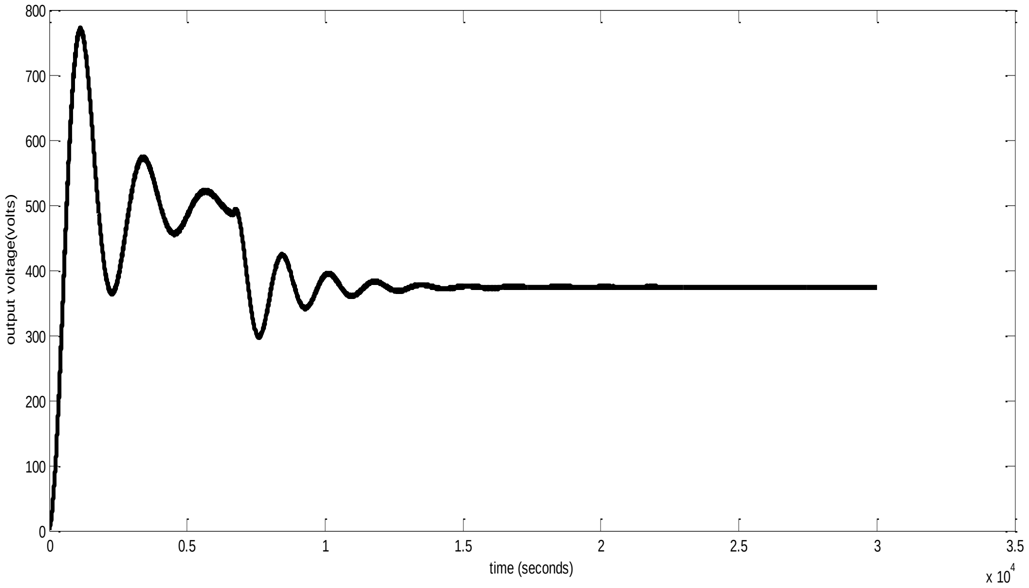

Fig. 4.5:Output Voltage Vs time

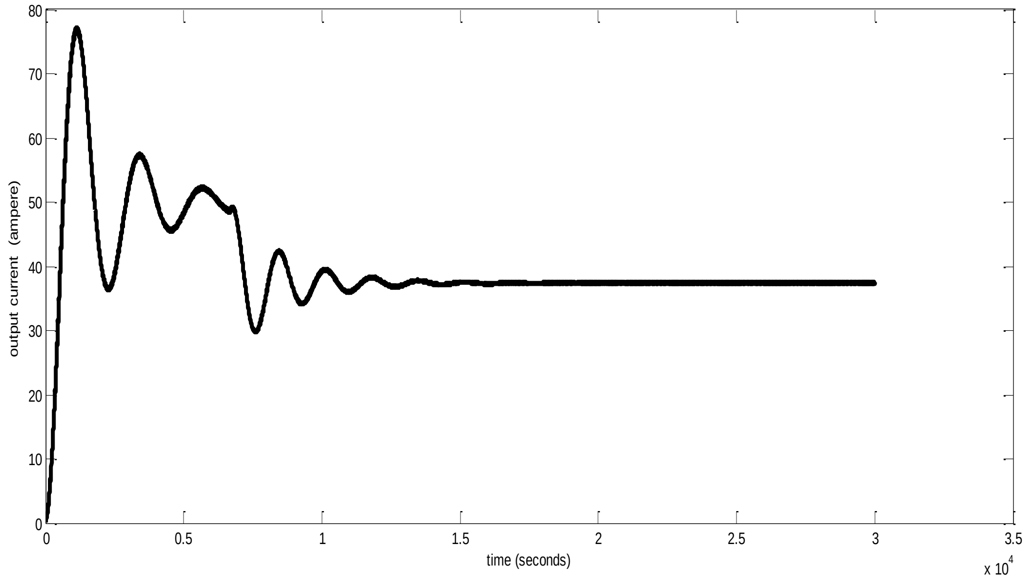

Fig. 4.6: Output Current Vs time

The average output voltage is obtained to be around 380 V. The average output current is obtained to be around 38 A.

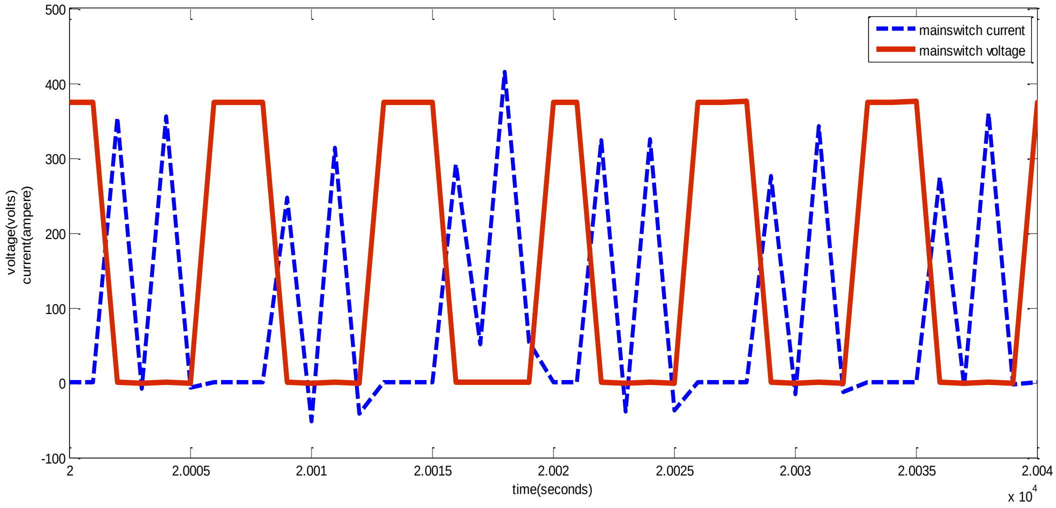

Fig. 4.7: Main Switch Current and Voltage Vs time showing ZVS

Before the main switch is turned ON the anti-parallel diode of the main switch is turned on. The main switch voltage has a slope by the snubber capacitor when the main switch turns off. The waveform shows that the main switch operates at zero voltage condition

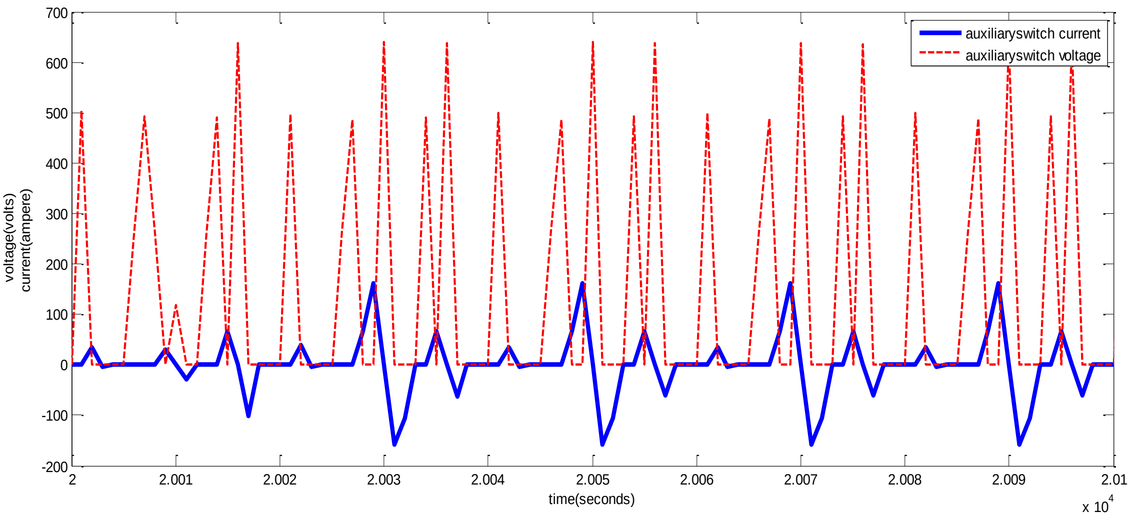

Fig. 4.8: Auxiliary Switch Voltage and Current Vs time showing ZCS

As the resonant inductor resonates with resonant capacitor a sinusoidal current is obtained. The auxiliary switch is turned ON with ZCS by resonating between the resonant inductor and capacitor. During the Zero voltage condition the anti-parallel diode assists the auxiliary switch to turn OFF.

4.3 CONCLUSION

The proposed boost converter is simulated in MATLAB and the output current and voltage waveform are obtained. The current and voltage waveform of main switch and auxiliary switch are observed showing zero voltage switching and zero current switching.

CHAPTER **5**

CONCLUSION AND FUTURE WORK

5.1 CONCLUSION:

In this thesis a soft switching Boost converter using an auxiliary resonant circuit is proposed. In this paper the schematic diagram of the converter and each mode of operation are discussed thoroughly. Each mode of operation are analysed by simulation using MATLAB-Simulink software. It is experimentally seen that the main switch and the auxiliary switch operates for the soft switching. The main switch is turned ON and OFF by the zero voltage switching (ZVS). Whereas the auxiliary switch is turned ON in zero current condition (ZCS) and turned OFF in zero voltage condition (ZVS). The switching losses are minimized by soft switching and efficiency of the boost converter is improved.

5.2 FUTURE WORK:

The proposed Boost Converter would be fabricated physically and the simulation and experimental results would be matched. The stability and efficiency can be further improved. The response of the boost converter can also be improved. The proposed boost converter can be integrated with solar array as a source and the overall performance can be checked.

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APPENDIX

250mV input boost converter for low power application

This project concerns about low power boost converter designed to operate at very low input voltage of 250mV. It's the voltage range of micro energy sources such as photo voltaic cells. The PCB prototype will provide a regulated maximum output voltage of 3.3V with 70% of maximum efficiency. The low power range of micro energy sources requires highly efficient circuit adaptation. The proposed converter design is very attractive for low power application power supply. The converter works without any external power supply for the control logic. New energy sources like single solar cell modules, thin-film batteries or micro fuel cells have been innovated in the last years. These sources have higher energy density than the traditional power supply sources. The traditional power supply sources such as Li-Ion or Ni-MH batteries have some significant limitations in terms of supply current and voltage. Hence we are trying to design a circuit highly efficient to work with input power of very few hundreds of μWs with maximum life time.

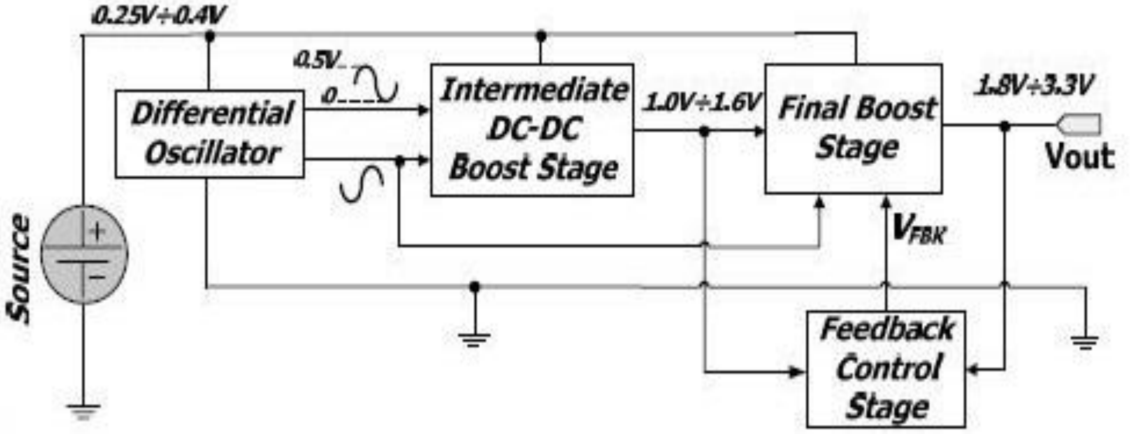

Fig. 1: Circuit Architecture of DC-DC Boost Converter

The proposed circuit consists of 4 main buildings. They are

i. Cross coupled differential oscillator
ii. Intermediate Boost Stage
iii. Final Boost Stage
iv. Feedback Control Stage

1.1 Cross coupled Differential oscillator

The circuit consists of a cross-coupled pair of zero threshold voltage mosfets to implement the negative resistance required for circuit oscillation. The oscillator generates a sinusoidal waveform with ∼0.5V peak-to-peak amplitude and 0.25V DC offset. The oscillation frequency of DC-DC boost converters, is fixed at ∼170 kHz. Increasing frequency leads to higher efficiency in boost DC-DC converters, since this allows using smaller inductors with lower parasitic resistances, thus decreasing related power losses. At the same time, higher frequencies lead to a higher power consumption of comparators required to control MOSFET switches. The use of cross coupled differential scheme is adopted because

- Noise and disturbances are reduced.
- MOSFET switches can be biased directly through the inductors.
- Guarantees the correct turn on and turn off of the MOSFET switches.

The MOSFET used in the circuit is ALD110800 having zero threshold voltage. It allows taking an input of very low voltage of 250mV. Diodes at the oscillator outputs are inserted to limit maximum oscillation amplitudes.

1.2 Intermediate DC-DC boost stage

This stage comprised of three blocks. i.e

1. Voltage clamp
2. First boost stage
3. Second boost stage

The voltage clamp stage is used to add to the control signal V_{osc+} and V_{osc-}generated by the differential oscillator a DC-offset voltage equal to the threshold voltage of the MOSFET switches of the two boost converters M3 and M4, which is ∼0.6 V.It allows the MOSFET switch of both first and second boosts stage to operate with 50% duty cycle. Thus each boost converter doubles its input voltage and the final 4x V_{source} needed for the FBS comparator supply is generated. Either increase or decrease in the duty cycle of the MOSFET increases the power loss in it.

1.3 Final boost stage

It is a conventional DC to D boost stage which converts voltage from 250mV to 3.3V.PWM control signal is generated by comparing the sinusoidal voltage provided by the differential oscillator to the constant control voltage generated by the feedback control stage, V_{FBK}. The comparator performing this operation is the most critical component for the efficiency of the whole circuit To achieve a high efficiency, we used the low-voltage and low-power rail-to-rail comparator ON Semiconductors NCS2200.Despite the low power consumption (minimum supply voltage ∼0.85V and 15μA bias current), this comparator features very low output voltage rise and fall times (20ns with a load capacitor of 50pF, corresponding to the M6 input capacitance, thus allowing strongly reducing power losses at MOSFET switch turn-on and turn-off and significantly improving the efficiency of the whole DC-DC boost converter. FBS is the real DC-DC boost stage converting the power provided from the micro energy source, hence maximizing its efficiency is crucial to improve the efficiency of the whole converter.The inefficiencies of other building blocks lead to much smaller energy dissipation, thus penalizing less the whole circuit efficiency, as the power they handle is only a relatively small fraction of the total power available from the micro energy source.

1.4Feedback Control Stage

The circuit is consists of an error amplifier and a compensation network required to assure circuit stability. The error amplifier is used to amplify the voltage difference $V_{OUT,SC} - V_{REF}$$V_{REF}$is the reference voltage of the feedback control network. Here resistors are used to limit the maximum current through the diodes. So Thus, $V_{REF}$is approximately given by the knee voltage of the diode. Of course, this solution suffers from the poor precision due to unpredictable variations of the electrical characteristics of the diodes with process and temperature, but has also the great advantage of strongly reducing the power consumption compared to more precise band gap voltage reference solutions.$V_{OUT,SC}$is the output voltage, scaled down by the variable resistance divider, which is comprises of R1 andR2. Changing the resistance R1 allows setting the output voltage *Vout*.

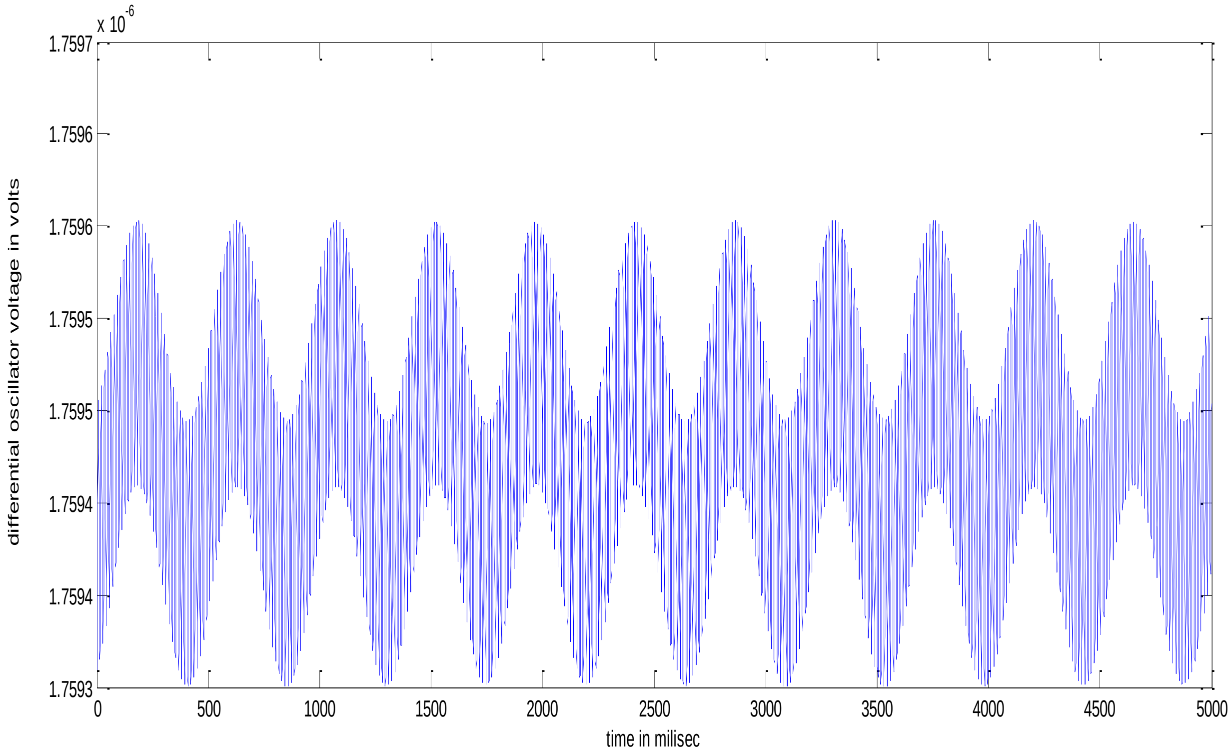

Fig. 2. Differential Oscillator Voltage Vs Time

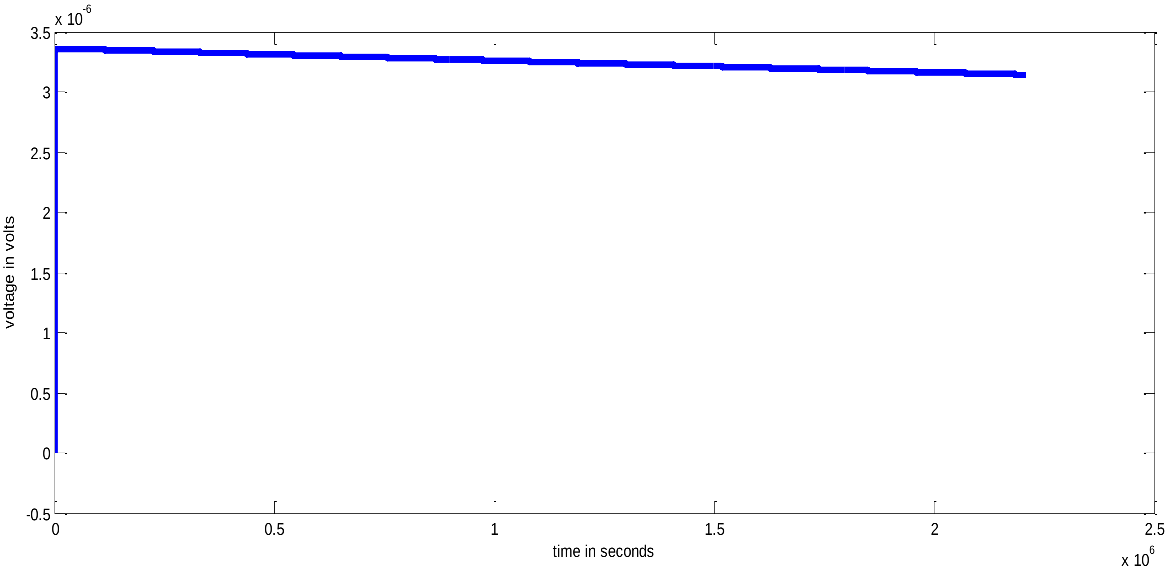

Fig. 3. Output Voltage Vs time

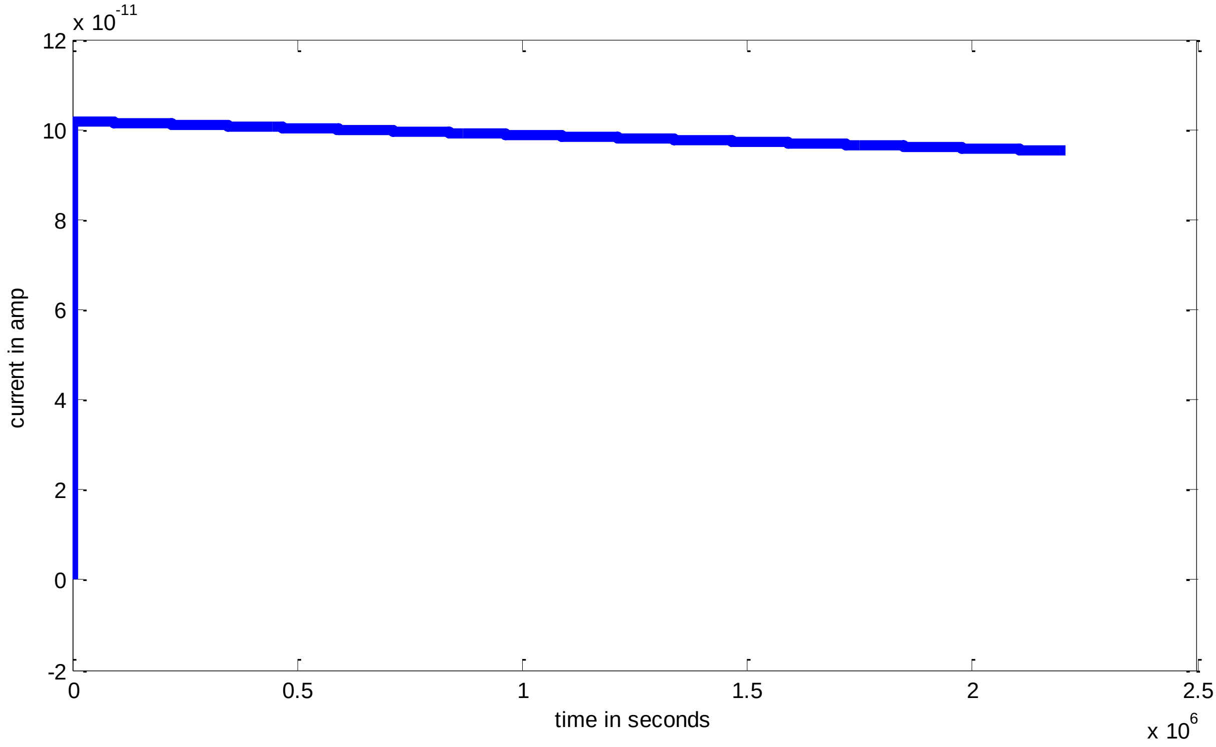

Fig. 4. Output Current Vs time