MULTIPLE INPUT MULTIPLE OUTPUT BUCK-BOOST CONVERTER

A THESIS SUBMITTED TO GRADUATE SCHOOL OF APPLIED SCINCES OF NEAR EAST UNIVERSITY

BY
Mohamed Asmaeil Amhimid Alqamoudi

In Partial Fulfilment of the Requirement for the degree of Master of Science in Electrical and Electronic Engineering

NICOSIA, 2018

Mohamed Asmaeil Amhimid Alqamoudi

MULTIPLE INPUT MULTIPLE OUTPUT BUCK-BOOST CONVETER

NEU 2018

MULTIPLE INPUT MULTIPLE OUTPUT BUCK-BOOST CONVERTER

A THESIS SUBMITTED TO GRADUATE SCHOOL OF APPLIED SCINCES OF NEAR EAST UNIVERSITY

BY
Mohamed Asmaeil Amhimid Alqamoudi

In Partial Fulfilment of the Requirement for the degree of Master of Science in Electrical and Electronic Engineering

NICOSIA, 2018

Mohamed Asmaeil Amhimid Alqamoudi: MULTIPLE INPUT MULTIPLE OUTPUT BUCK-BOOST CONVERTER

Approval of Director of Graduate School of Applied Sciences

Prof.Dr.Nadire CAVUS

We certify this thesis is satisfactory for the award of the degree of Masters of science Electrical and Electronic Engineering

Examining committee in charge:

Prof.Dr. Seyed Hosseini	Supervisor, Department of Electrical Engineering, University of Tabriz
Assist.Prof.Dr. Lida Vafaei	Department of Mechanical Engineering, NEU
Prof.Dr. Mehrdad Hagh	Department of Electrical engineering, University of Tabriz

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct, I also declare that, as required by these rules and conduct, I have fully cited and references all material and result that are not original to this work.

Name, last name:

Signature:

Date:

To my family…

ACKNOWLEDGEMENTS

My study at the Near East University period three years learned this, this is unable to the completion of this thesis, thank you to all my professors. The guidance of Professor Seyed Hossein Hosseini provided assistance to the consistency of the steps of accomplishing this work which was preceded by his efforts during the power electronics in which I found decisive influence on the ability to follow up many of the results and studies of other researchers which helped a lot in completing this thesis.

I will not forget the patience and their supportive attitude towards my family during the period of study.

ABSTRACT

Power electronic circuits use in most electrical and electronics devices, this way it always needs development to keep pace with the continuous development of these devices. The required performance of the power electronics circuit varies according to the device used and it can be classified according to that requirement, so it can be classified in more than one way. Precisely, the subject of this thesis is the study and analysis power electronic circuit that can handle multi input sources and multi output. Multiple input Multiple output, Buck-Boost Converter (MIMO-BBC) topology received all the attention of this thesis, The first goal is to achieve high reliability, the first goal is to achieve high reliability so that the circuit can be fed by a larger number of sources and analysis the expected problems, the challenge is floating-point problem, and how much the transistor control strategy could run. The control strategy mode 1 and mode 2 is study for the purpose of choosing the best control strategy to achieve the high reliability, One control strategy is built on one transistor to be opened at a time in the input stage, while the other control strategy is built on all transistors being opened at the same time, Where many advantages and disadvantages exist, such as reducing the stress in the transistors and the quantity of the harmonics in the output voltage waveform. The floating-point problem in the terminal of the used capacitor in the system is solved by an appropriate control strategy.

***Keywords*:** Multi input; Multi output; Buck-Boost Converter; Direct Current Converter; Switching Strategy of Power Electronic Converters

ÖZET

Güç elektroniği devreleri, tüm elektronik cihazlarda daimi bir mevcudiyete sahiptir, bununla birlikte, çeşitli elektronik sistemlerin sürekli geliştirilmesi, ardından güç elektroniğinde, gerilim, akım, güç büyüklüğü. sağlanmalıdır. Güç elektroniği kaynağı, bunların gerektirdiği performansa göre değişmektedir, Bu nedenle, izolasyonu kullanmayan ve giriş ve çıkış aşamalarının her biri için birden fazla port kullanan, birden fazla yolla sınıflandırılabilir, bu tezin temel konusudur. Çoklu giriş Çoklu çıkış, Buck-Boost Converter topolojisi, bu tezin odak noktası olmakla birlikte, Asıl önemli olan kaynak sayısını arttırmak ve beklenen problemleri ele almaktan oluşan yüksek güvenilirlik elde etmektir, Giriş kaynaklarının sayısını artırma, zorluk kayan nokta ve transistör kontrol stratejisinin ne kadar koşabileceği. Mod 1 ve mod 2'yi kontrol etme stratejisi, en iyi güvenilirliği elde etmek için en iyi kontrol stratejisini seçmek amacıyla gözden geçirilir; Bu, her seferinde sadece bir anahtara çalışmak için kontrol zamanının anahtarlama üzerine bölünmesiyle yapılır. Birçok avantaj ve Transistörlerdeki gerilimi azaltmak ve çıkış voltajı dalga formundaki harmoniklerin miktarı gibi dezavantajlar bulunmaktadır. Sistemde kullanılan kapasitörün terminalindeki kayan nokta uygun bir kontrol stratejisi ile çözülür.

Anahtar Kelimeler**:** Çoklu giriş; Çoklu çıkış; Buck-Boost Dönüştürücü; Doğru Akım Çevirici; Güç Elektroniği Dönüştürücülerinin Anahtarlama Stratejisi

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AC:	Alternate Current
AC-AC:	Alternate Current to Alternate Current Converter
AVG:	Average
BBC:	Buck-Boost Converter
BBPC:	Buck-Boost Positive Converter
C:	Capacitor
D:	Duty Cycle
D:	Diode
DC:	Direct Current
DC-DC:	Direct Current to Direct Current
DT:	Duty Cycle Time Switch
L:	Inductor
Fs:	Frequency Switch
MIMO:	Multi Input Multi Output
MIMO-BBC:	Multi Input multi Output Buck-Boost Converter
MI:	Multi Input
MO:	Multi Output
t:	Time
Ts:	Time Switch
VL:	Inductor Voltage
Vi:	Input Voltage
Vo:	Output Voltage
P:	Power
R:	Resistor
S:	Second

CHAPTER 1

INTRODUCTION

1.1 Motivation

Due to the increasing demand for the use of various renewable energy sources, multi-ports power electronics supplies are experiencing increased attention over the past decades. It is well known that renewable energy sources have great economic, environmental and reliability advantages, yet they require conversion circuits in order to benefit from their output power. This explains the great attention towards the research in the field of power electronics. The researchers are targeting to reduce the cost, the size, the price and weight of the designed conversion circuit, and to increase the efficiency, the reliability and flexibility of the circuit

Generally, DC-DC converters are used as an intermediate between renewable energy source and inverter. They are used to reduce or increase the voltage level output of the renewable energy source. The inverter is used to convert the DC voltage to an AC voltage waveform, which may be used through linear and nonlinear loads or injected to the grid after passing a filter.

Among different DC-DC conversion topologies, in this thesis we are going to address Buck-Boost multi input multi output (MIMO) DC-DC converter. In this work, the effect of different number of inputs and outputs on the system performance is investigated, in other words, how the efficiency is changing when the number of ports increases. It is also important to study the relationship between duty cycle of the converter and the number of sources output that serve as input to the power electronics circuit. Furthermore, we encounter continuous and discontinuous mode of the converter. The main challenge of this topology is to reduce the number of inductors used in the system, which will cause a reduction in the size, the weight and the price of the designed converter.

1.2 Objective

The objective of this thesis is to study and analyze multi input multi output buck-boost positive converter. MICRO CAP 11 software will be used for simulating the circuit.

1.3 Structure of Thesis

The thesis work is organized as follows; first chapter covers the introduction of the work, explaining its importance and motivation. While the second chapter explains the theory of the proposed circuit and reviews the related literature. Chapter three presents the converter design stages including the basic features of the circuit elements and determines the values of the elements by using the designed equations. In Chapter four, MIMO converter topology selection is explained. The simulation results of the complete circuit are discussed in chapter five. Finally, chapter six gives the summary of the work, and also suggests future work and conclusions.

CHAPTER 2

DC-DC CONVERTERS

2.1 Introduction

This chapter discusses the basic principles and theory of DC-DC converters, its functions and classification. The chapter also reviews the basic principles of choppers under continuous mode operation. At the end of the chapter, buck-boost converter topology is explained in details.

2.3 DC-DC Converters Goals (Aims)

DC-DC converter aims are:

- To converter DC to DC voltage under stable operation
- To protect supplied system and to control the ripple of the output voltage
- Isolation between the renewable energy source and the inverter

DC-DC converter is used to provide an appropriate direct current for various electronic applications. Due to the diversity of electric power circuits and requirement specifications for different applications power electronics. DC-DC converters can be classified according to the following block diagram (Jafari et al., 2012).

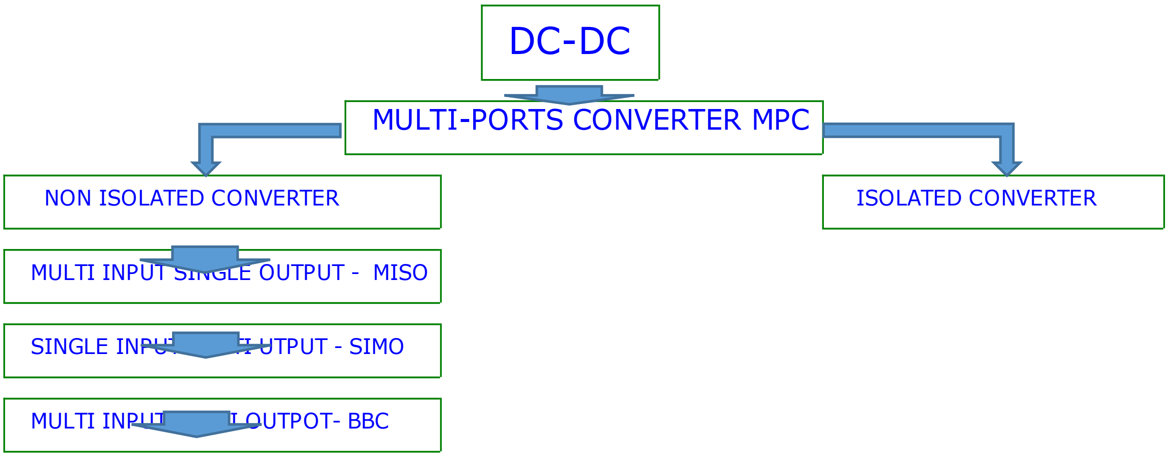

Figure2.1: Block diagram classified DC-DC converter

2.3 DC Choppers

Figure 2.2 shows a voltage source, a switch and a load resistance connected together in series. The switch is suitable for the circuit, and it could be a transistor with high opening and closing speeds (i.e. high operating frequency). It is often a one-way switch where current flows in one direction(Rashid, 2012).

The function of the switch is specified according to Figure 2.2. The duty cycle is determined by the opening period (DT) as well (1-D)T the close period, the standard equation is:

$$V_o = DV_{in}$$

Where

D is operating time period "ON "

V_o is voltage output

V_i is voltage input

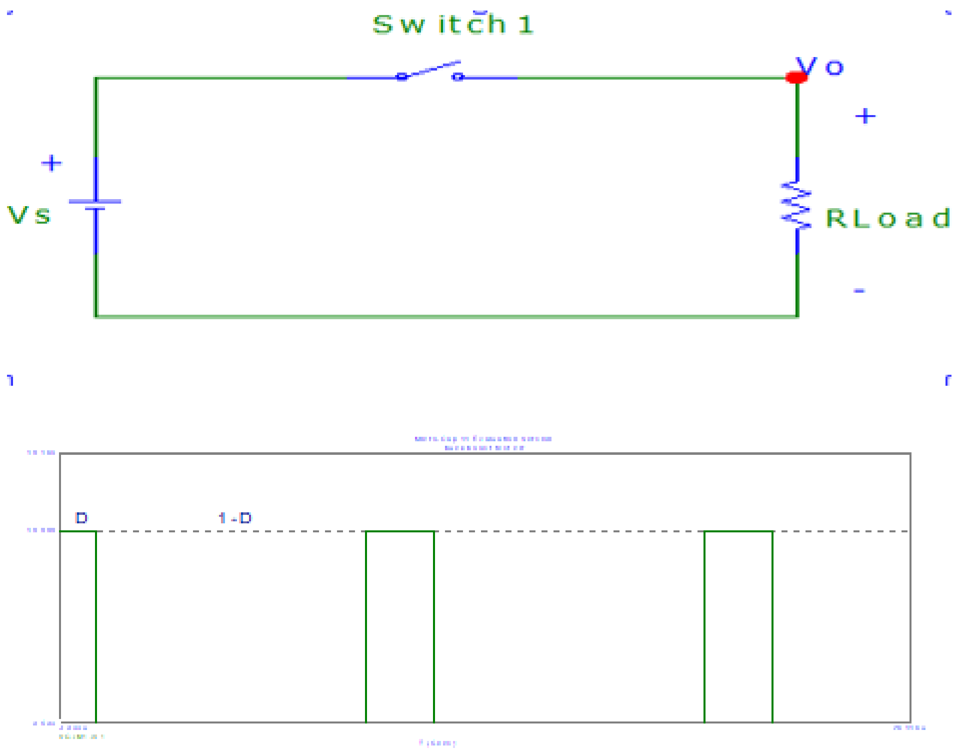

Figure2.2: Switching power,circuit and duty circuit (Baylor, 2017)

2.4 Buck-Boost Positive Converter (B-BPC)

Buck-Boost converter refers to a DC-DC converter that can step down or step-up positive or negative output voltages. This circuit configuration may include an isolation transformer and is refered to as isolation converter, if an isolation transformer is not used, it is known as non-isolation converter. And also it has different configuration depending on the number of elements which we can select in order to achieve the required costs, efficiency, modularity, reliability and flexibility. So Buck-Boost converters are useful for applications where reduction the cost at high operating performance is required (Banaei et al., 2014).

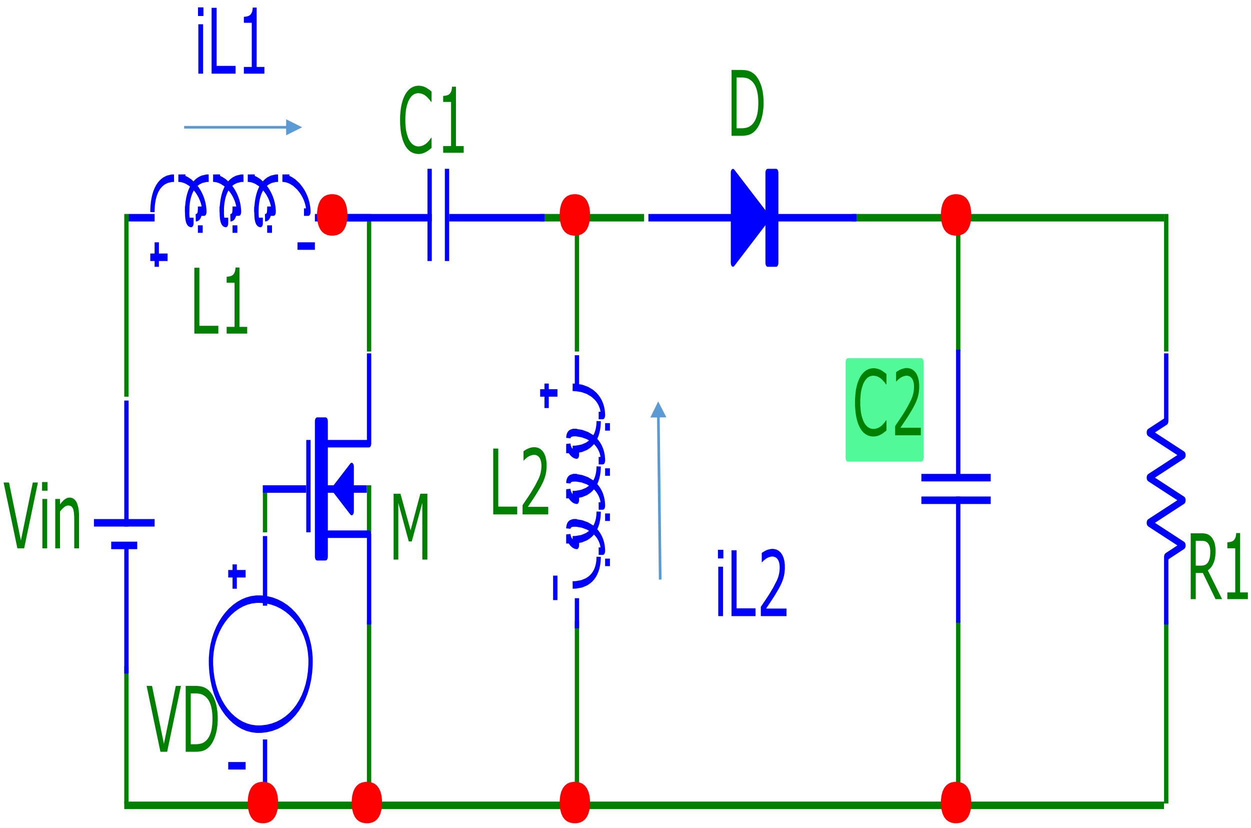

Figure2.3: Buck - Boost positive converter (Baylor, 2017)

Figure 2.3 shows Buck-Boost positive converter circuit . The output voltage and current are both positive. It is assumed that the circuit is working under normal operations, meaning it is working in continuous mode, which means I_{L1} and I_{L2} will not reach to zero value (Banaei et al., 2014). If the currents in I_{L1} and I_{L2} reaches zero, then it is said that the converter is working under discontinuos operting mode(Banaei et al., 2014).

2.5 Transfer Function

Transfer function for Buck-Boost converter can be obtained by applying Kirchhoff's law to the converter circuit in Figure 2.3. As shown in the following equations (Baylor, 2017):

$$-V_{in} + L_l\frac{diL1}{dt} + Vc1 + L_2\frac{diL2}{dt} = 0 \tag{2.1}$$

The average voltage across L_1 and L_2 is zero. From Figure 2.3 we have:

$$Vc_l = V_{in} \tag{2.2}$$

Applying Kirchhoff's law at output stage yields:

$$< i_{L2} >_T = < i_D >_T = I_{out} \tag{2.3}$$

In continuous conduction, there are two states as shown in Figure 2.4 below.

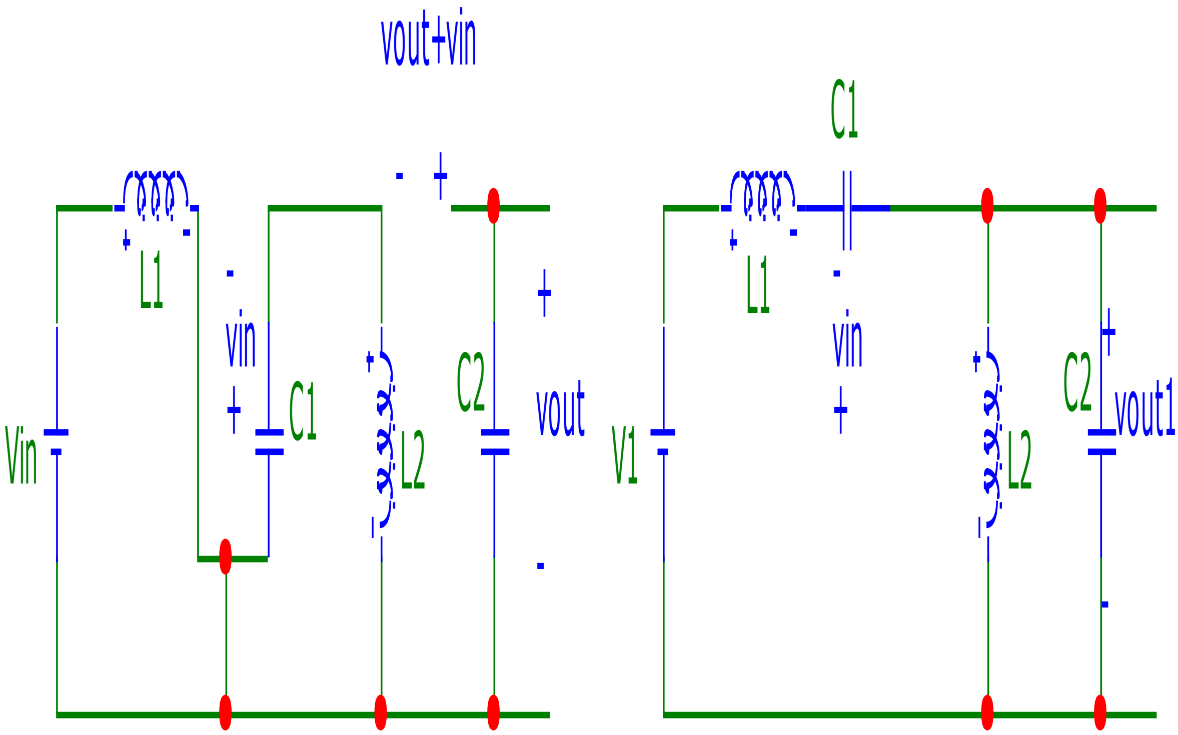

Figure2.4: Switch closing where DTs and switch opening where (1- D)Ts (Baylor, 2017)

State 1:

When the switch is closed, the diode is reverse biased. The current i_{L1} will increase at the rate of

$$L1\frac{diL1}{dt} = V_{in}, \qquad 0 =< t = < DTs \tag{2.4}$$

State 2:

When the switch is opened. The inductor L1 is charging and the diode is forward biased, and i_{L1} decrease at the rate of

$$\frac{diL1}{dt} = \frac{-Vout}{L1}; \qquad DT < t < Ts \tag{2.5}$$

Where L1 is discharged. Ther average voltage across L1 for one switching period is give as

$$\frac{(V_{in})DTs+(-Vout)(1-D)Ts}{Ts} = 0 \tag{2.6}$$

Simplifying (2.6), gives the relationship between V_{output} and V_{input} as (Baylor, 2017):

$$Vout = \frac{D}{1-D} * V_{in} \tag{2.7}$$

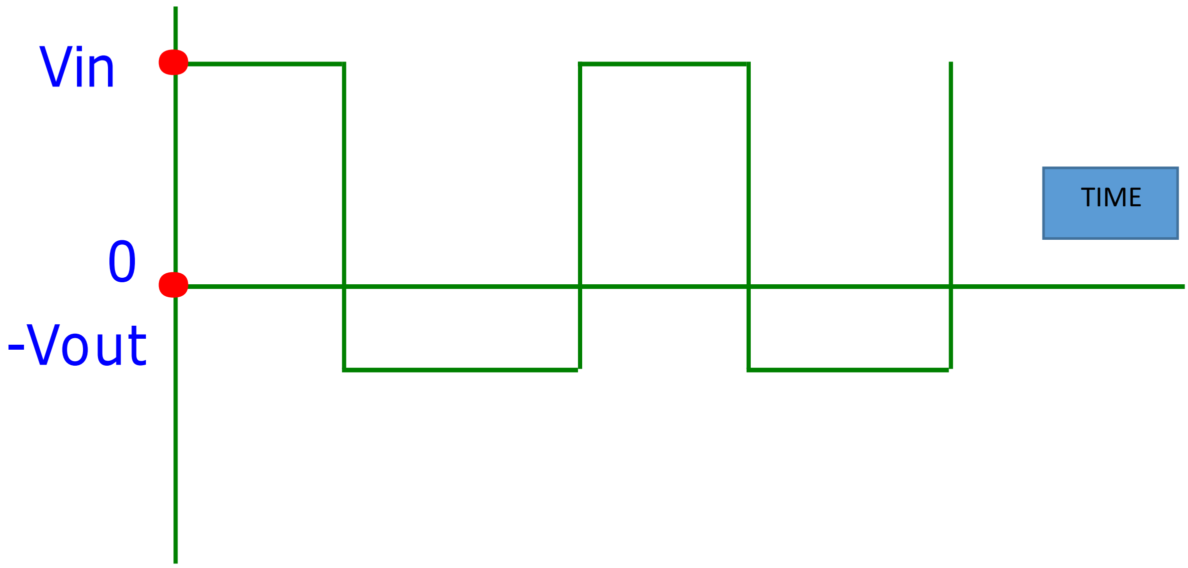

Figure2.5: VL in continuous conduction

Thus the converter is opertaing in buck mode when D < 0.5, and in Boost mode when D > 0.5 , and with equal input and output voltages when $D = \frac{Ts}{2}$ (the converter may be sued as an isolation in this mode of opertaion).When the converter input power is equal to the output power,then we have (Baylor, 2017).

$$\mathrm{I}out = \frac{(1-\mathrm{D})}{\mathrm{D}}\,\mathrm{I}in \qquad (2.8)$$

Table 2 .1: Closing and opining switching

Switch close	Charging	Charging	Discharging	Discharging
Switch open	Discharging	Discharging	Charging	Charging

2.6 Continuous Moode and Discontinuous Mode

The continuous mode opertaion boundary of the inductor current I_{L1} is shown in Figure 2.6 below. The boundary represents the region where the current is guranteed to be nonzero

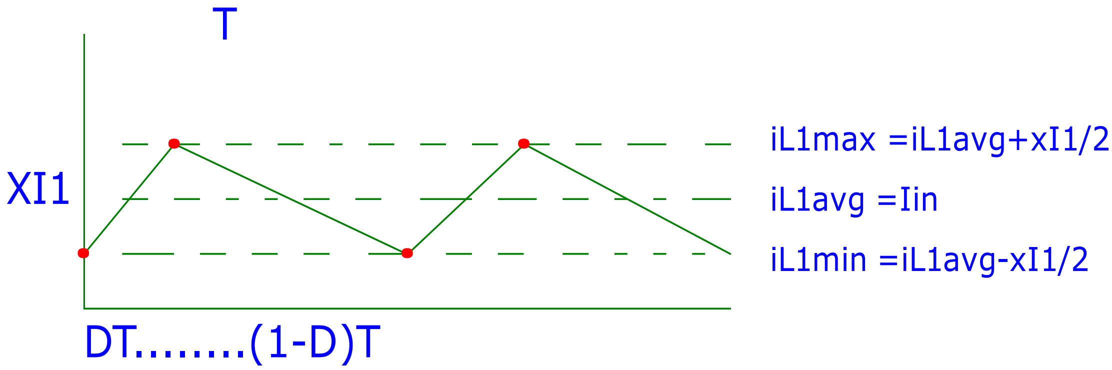

Figure2.6: Inductor L1 current continuous mode (Baylor, 2017)

From Figure 2.6 and equation 2.4, and when the switch is open (L1 is "discharging") we have

$$\Delta I1 = \frac{Vout}{L1}(1-D)T = \frac{Vout(1-D)}{L1*f}\ ; \quad f \text{ is switching frequency} \qquad (2.9)$$

The boundary of continuous conduction operation for L1 is when $I_{L1min} = 0$, as shown in Figure2.7.

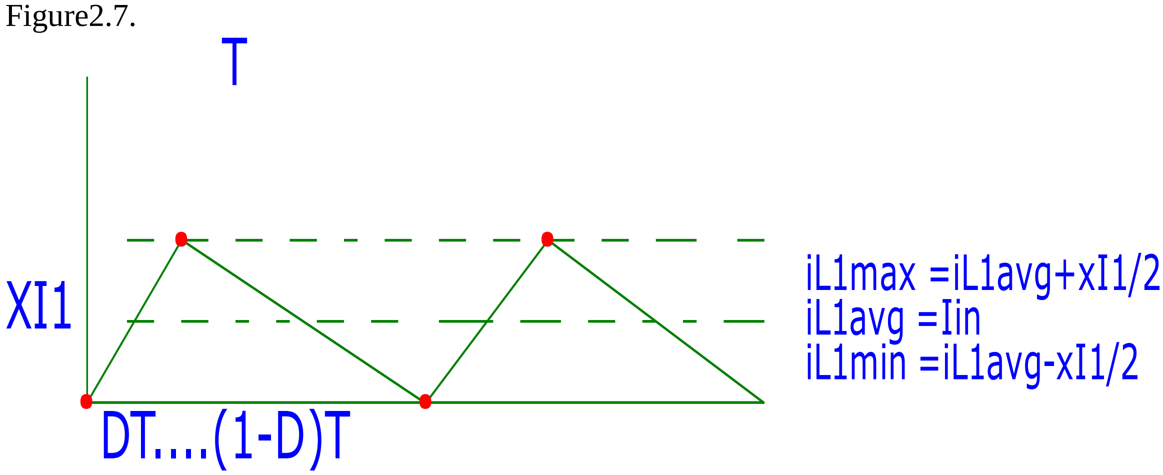

Figure2.7: Inductor current IL1, boundary of continuous mode conduction

$$2Iin = \frac{Vout(1-D)}{L1BOUNDARY*f}(1-D)T = \frac{Vout(1-D)}{L1*f}$$; and as D approaches unity,

$$L1 > \frac{V_{in}}{2*Iin*f} \qquad (2.10)$$

Similar with L2:

$$\Delta I2 = -\frac{Vout}{L2}.(1-D)T = -\frac{Vout(1-D)}{L2*f}\ ; f \text{ is switching frequency} \qquad (2.11)$$

And

$$L_2 > \frac{\text{Vout}}{2 * Iout * f} \qquad (2.12)$$

To guarantee continuous conduction mode it is required to have high enough values of I_{in} and F (Baylor, 2017).

2.7 Conclusion

Buck-Boost Positive Converter will be used to build the MIMO-BBC. Equations in this chapter will be used to determine the values of the elements to ensure that the circuit operates in a continuous mode as well as to explain the behavior of the circuit.

CHAPTER 3

MIMO CONVERTER TOPOLOGY

3 INTRODUCTION

In this chapter the MIMO-BBC that has four inputs and three outputs will be built. Also, the goal is try to use the least number of elements and keeps a high degree of reliability as well as using the method of linking elements to be tested to achieve increases in reliability. The flexibility of the system can be increases the number input dc sources to M, as well as increase the number of output stages to N.

3.1 Build the Topology of MIMO-BBC

The aim of this work is to design power electronics source that has a multi ports in both input and output. The voltage of the power sources may be equal or different from each other. This depends on the type of energy sources used and other factors. Each energy source has different voltage-current curve characteristics. In this work it will be assumed that all sources are having the same volt-current characteristics. Thus, the number of input sources can increase as many as M

$$V_{in1},\ V_{in2},\ \ldots\ldots..,V_{in,M} \tag{3.1}$$

and number of output stage canbe as many as N

$$V_{output1},\ V_{output2}\ ,\ \ldots\ldots..,V_{output,N} \tag{3.2}$$

Based on the above information it can suggest that equal four sources with value 12 V_{dc} as inputs these sources V_{in1}, V_{in2},V_{in3} and V_{in4} are connected with four inductors L_1, L_2, L_3 and L_4 as shown in Figure 3.1.

Where V_{in1} supplies branch 1 by current I_{n1}, then the first Buck-Boost converter will exist and will consist of Vin1, inductor 1, MOSFET 1 and branch 1. Switch M_1 opens, the current I_{in1} that is coming from V_{in1} to branch 1 flows. The result in work of both inductor 1, inductor

9, MOSFET 1 and Branch 1 to produce the $V_{output\ 1}$ based on the values of operation time V_{in1} with value 0.7μs for each switch where the time switch T_s is 10 μs in this case the converter will work as Buck converter, from equation 2.7 and when we assume used ideal components can get:

$$\text{Vout} = \frac{0.7}{10-0.7} * 12 = \ 0.903 \text{ V} \qquad (3.3)$$

The 0.903V just preduce from V_{in1}.

Similarly, V_{in2} also will be supplied branch 1 after M1 closed, and the switch M2 will be opened for flow current to branch 1, the results in operate of both inductor 2 and inductor 9 again to produce the output 1 based on the values of duty cycle's V_{in2} ,and add 0.906V to output of branch 1 similarly, the V_{in3} and V_{in4} will work with branch 1 in the same way that both Vin1, V_{in2} remember that "the duty cycle for M1, M2, M3, M4 have equal width and the different opening time, for four switches the output 1 is:

output 1=0.903v*4=3.612vdc.

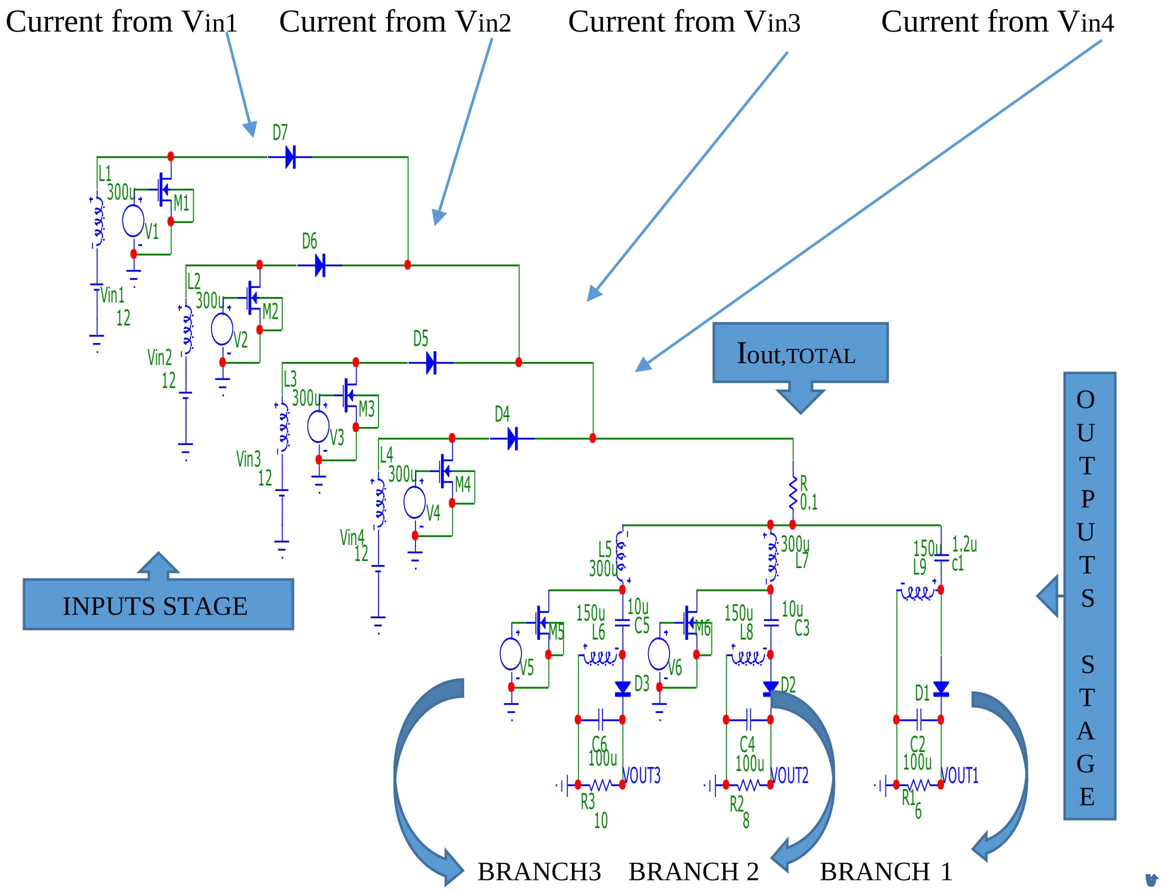

Figure 3.1: MIMO-BBC, circuit diagram

Based on above can write equation 3.4 as:

$$I_{\text{input, branch 1}} = I_{\text{in ,TOTAL (FROM ALL SOURCES)}} - I_{\text{input, branch 2}} - I_{\text{input, branch 3}} \quad (3.4)$$

Where the current " $I_{\text{in, TOTAL (FROM ALL SOURCES)}}$ " is the summation of all currents from sources $I_{in1}+ I_{in2} +I_{in3}+ I_{in4}$. The current "$I_{\text{in, TOTAL (FROM ALL SOURCES)}}$" also will feed other branch 2 and branch 3, where another Buck-Boost converter exists between inputs stage with branch 2 and branch 3. This type of configuration, meaning a current will feed different banches and is applied from converter to another one at the same circuit board achieves power electronic circuit having multi ports for outputs configuration.

3.2 Input Stage

Figure 3.2 shows the input stage, which consists of four DC voltage sources. The sources are aarranged as a column to produce an electric current that feed a row of output stages. After passing the total current through protection resistance "FUSE RESISTOR "each DC voltage source is connected in series with its own inductor and with reliabilty diode. The DC voltage source may be an output of roof of photovoltaic "PV" system, winding energy source or a hybrid of them.

3.2.1 Diode reliability

Which also called as "diode protection”. It is a diode which is connected in series with the DC voltage source and used for protectin. When short circuit occurs between drain and source of the MOSEFET, the diode will cause a floating-point at anode each D_4 D_5, D_6, D_7. In case we have partial damage in any of the voltage sources, or if there is any failure in any of them, the corresponding voltage source will have no influence on the system because of the compensation from the rest of the sources. This will improve the system’s reliability in whole. The only disadvantage of these diodes is the increase of the power loss and cost.

3.2.2 Floating point problem

When switch M_1 is closed, one terminal for L_1 is connected with ground, where a resistance between the voltage source and the drain of the MOSEFET is small, the anode of the diode D_7 is connected to the ground also. This will cause the terminal of C_1 in floating-point, meaning, the terminal of the capacitor is not connected to anything, floating. It is assumed (idealy) that the backward inverse of the diode is very high, which implies that the Buck-Boost positive converter is not in operation, but accordingly to the control strategy Figure 3.4 or Figure 3.6 the switches M5 and M6 will be open. The terminal of C1 will be connected through L5 and L7 with ground connected. By doing so, the problem of floating-point the terminal of the capacitor C1 is solved and the output stage branch 1 works in the normal operation.

3.2.3 Number of input ports

The number of DC input voltage of M source can be increase as

$$V_{in1},\ V_{in2},\ V_{in3},\ V_{in4},\ldots\ldots\ldots\ldots\ldots\ldots ,V_{inM} \qquad (3.6)$$

$$I_{\text{FUSE RESISTOR}} = I_{\text{INPUT}} = I_{\text{branch 1}} + I_{\text{branch 2}} + I_{\text{branch 3}} \qquad (3.7)$$

Increasing the number of DC sources increases the reliability of the system as a whole, where the electrical capacity increseaes.

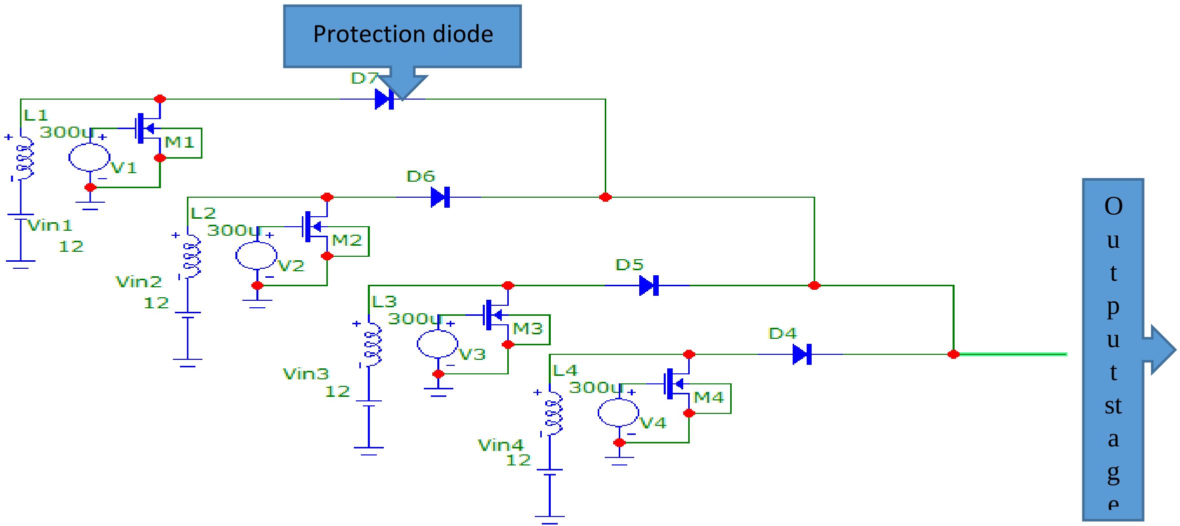

Figure 3.2: Inputs stage

3.2.4 Output stage

Number of output voltages can increase up to N ports. Figure 3.3 shows output stage that suggests a three outputs parts, branch 1, branch 2 and branch3. Where each part works independently of the other parts, this increases the system reliability as well as system flexibility. In addition to improvement of system operation and maintenance.

All three branchs were built to work on the installation to work as Buck, Boost and $V_{out} = V_{in}$ respectively, in this regard it can write that:

$$V_{output1}, V_{output2}, \ldots\ldots\ldots\ldots, V_{output,N}; \quad (3.8)$$

If M is a number of input sources and N is a number of outputs. In this regard it can estimate that number of elements that need to build circuit so:

The number of switches P is:

$$P = M+N-1 \quad (3.9)$$

The number of coil L is:

$$L = M+2N-1 \quad (3.10)$$

The number of diode D is:

$$M+N \quad (3.11)$$

The number of capacitor C is:

$$2*N \quad (3.12)$$

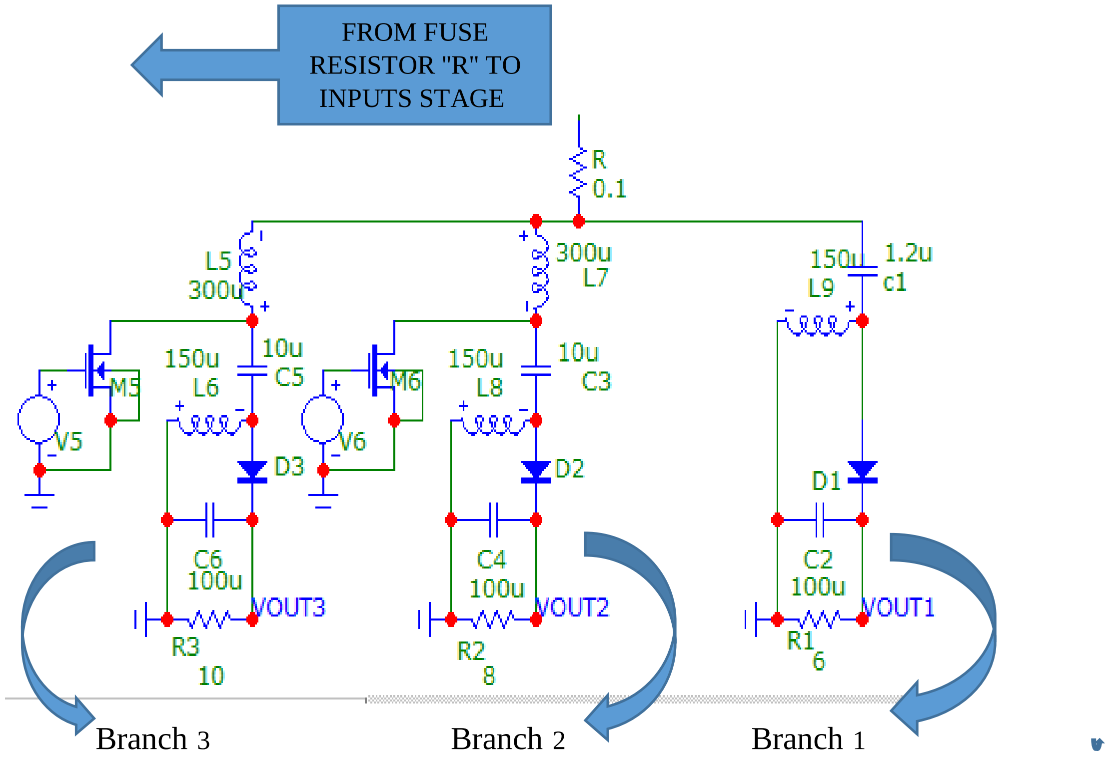

Figure 3.3: Output stage, three outputs

For Buck- Boost Positive converter the duty cycle is a control parameter which controls the value of the output voltage as

$$\text{Vout} = \frac{D}{1-D} * \text{Vin} \tag{3.13}$$

Operation time usage in three stage outputs for branch 1, branch 2 and branch 3 are different width as 0.7µs, 5µs, 7µs respectively to obtain the output voltage value, 3v,12v, 28v also respectively and at an ideal component.

3.2.5 Control strategy of input stage

The switches of input stage MIMO-BBC are fed by four pulses applied in each switch gate. The Turn off and turn on allows or blocks the current flowing from the voltage source to the elements of the Buck-Boost converter. The pulses are produced so the duty cycle of the switches produces the desired output voltage. The duty cycle is defined as the switch on time over the total switching time, or sampling time Ts. Two types of control strategy can be applied to the input stage, as follow

1. All gates are open at the same width of duty cycle and at the same time:

Then we have M1, M2, M3, M4, will open and close at the equal width pulses and at the same time without any delay between them, Period of switching ON shall be as a percentage of the total period Ts. Inductors, L1, L2, L3, L4 will charge when the switching opens to one level, switching OFF " Figure 3.5 and all diodes allow to currents flow to the load and started from more than zero, Figure 3.4 shown operation time (equal width and at same time) for switches (M, M2, M3, M 4) and pulses for switches M5 and M6 for another branches, it is a type 1 control strategy.

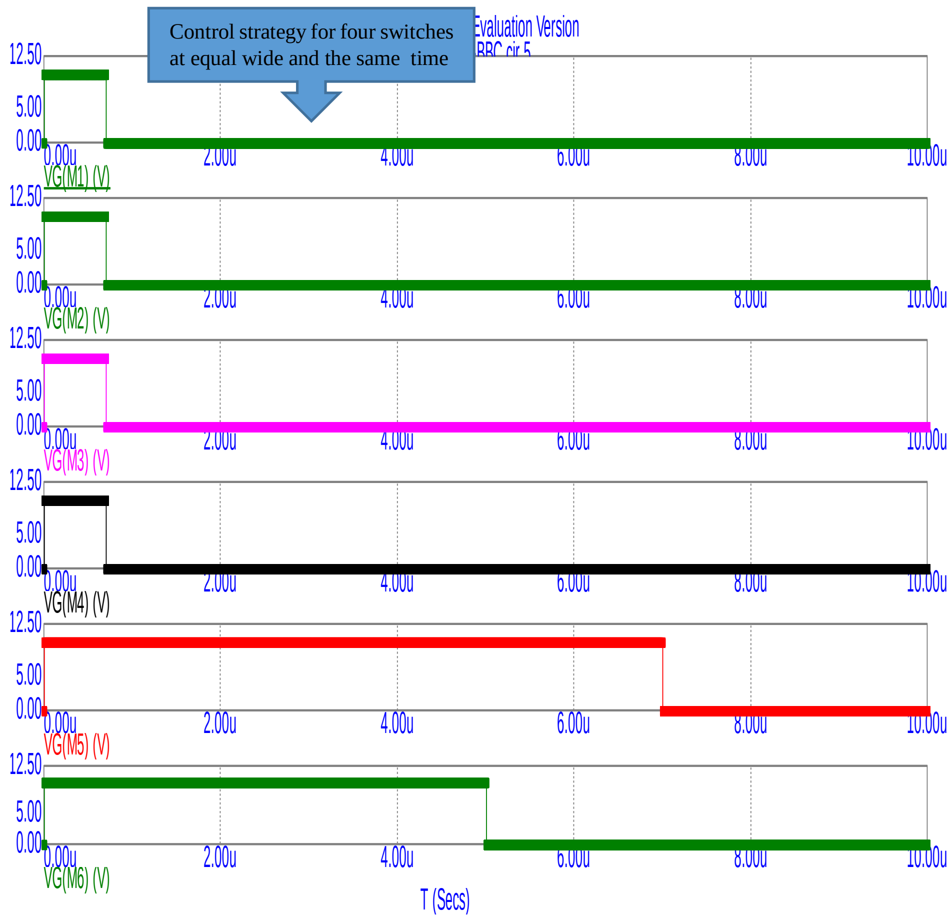

Figure 3.4: M1, M2, M3, M4 And M5 M6, one level type 1 control strategy

L1, L2, L3, L4 will charge at the same time from four V input sources, in this case all inductor will charge in one level Figure 3.5, so we can write:

$$| \Delta ILn | = \frac{V_n}{L} * Dn*Ts \quad (3.14)$$

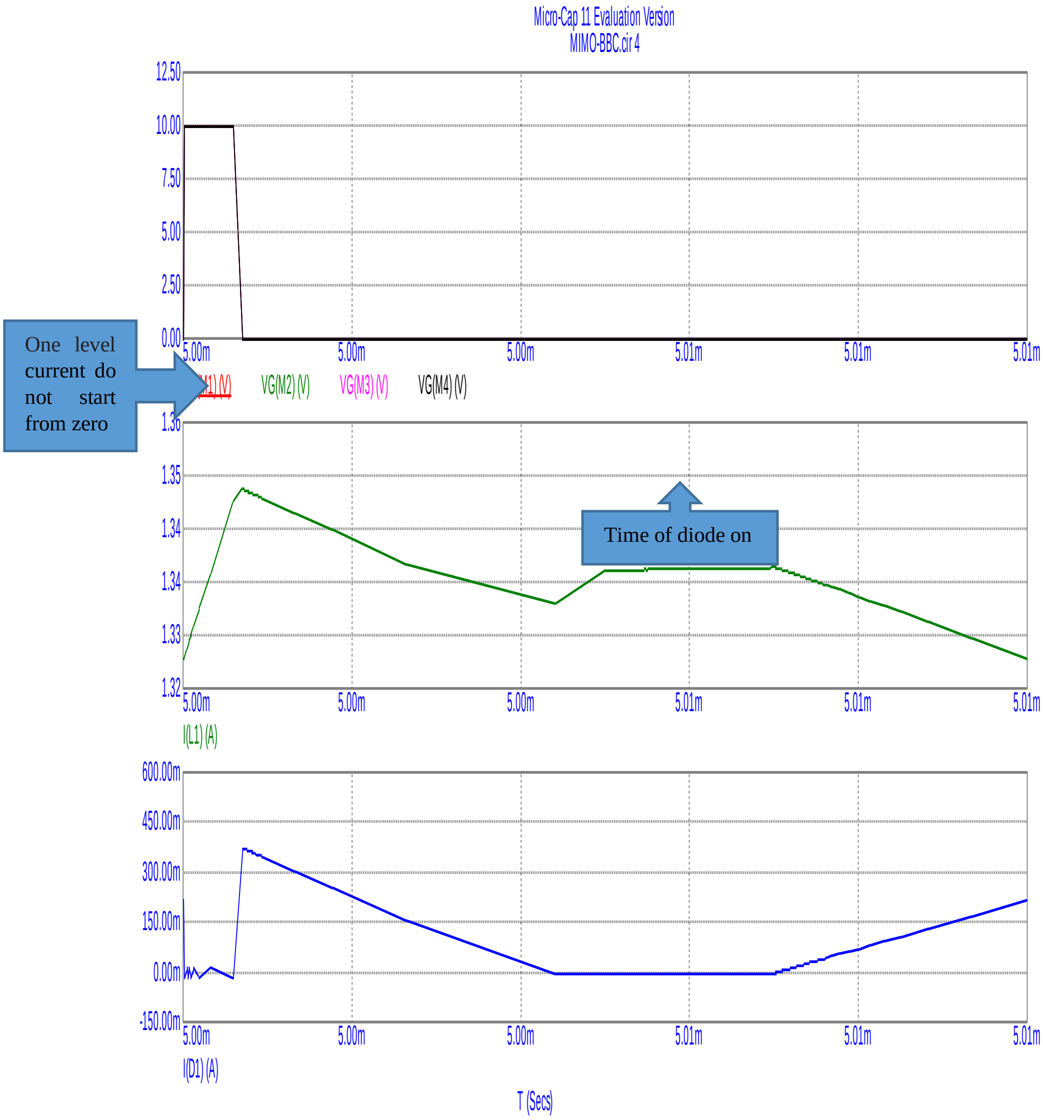

Figure 3.5: One level strategy control Ttype 1, IL1 and D1 current

When using this method, it is noticed that the switch will be under stress when we are using this method, and there will be an increase in the number of harmonics.

2. All gates are open at the same width of duty cycle and at the different time:

M1, M2, M3, M4, will be close and opened at the different time with a delay between them and equal width of operation time. Period of switching ON shall be as a percentage of the total period Ts, but that will limit the number of input source, When increase switching frequency can increases number of sources, Figure 3.6 shows that the control strategy for four level type 2 for all switches.

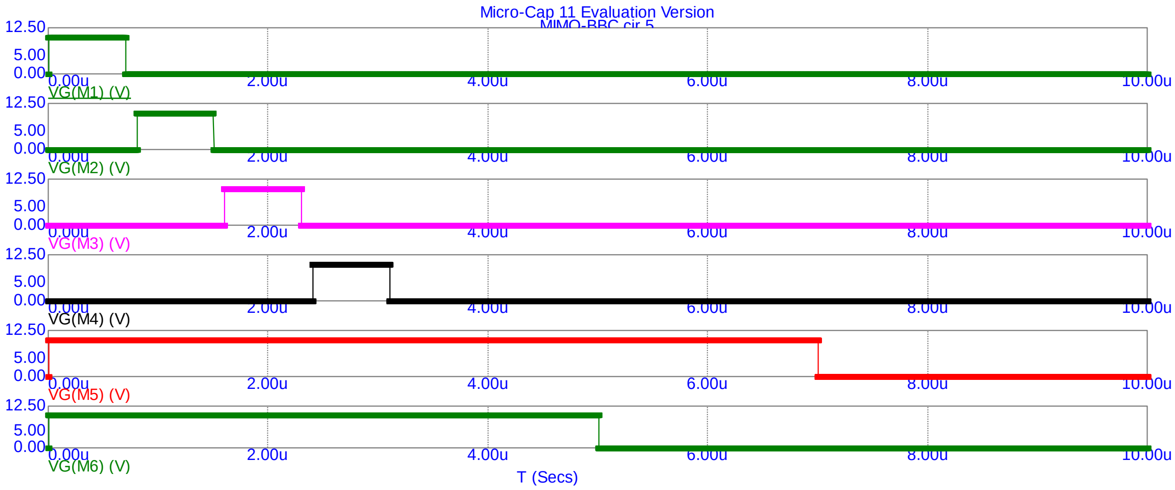

Figure 3.6: M1, M2, M3, M4, M4 and M6, for Llevel type 2 control Sstrategy

Inductors L, L2, L3, L4 will be charged to four levels, then all gates of the switches will close and all diodes allow currents flow to the load and was started from more than zero, IL1, IL2, IL3, IL4 will charge at the different time from four V input sources, in this case all inductor will charge in four level Figure 3.7, so we can write:

$$|\Delta\ IL_n| = \frac{V_N}{L} * D_n * T_s \qquad (3.15)$$

$$IL_n\ (max) = \sum_1^N |\ \Delta I\ | = \frac{1}{L} \sum_1^N V_n * D_n * T_s \qquad (3.16)$$

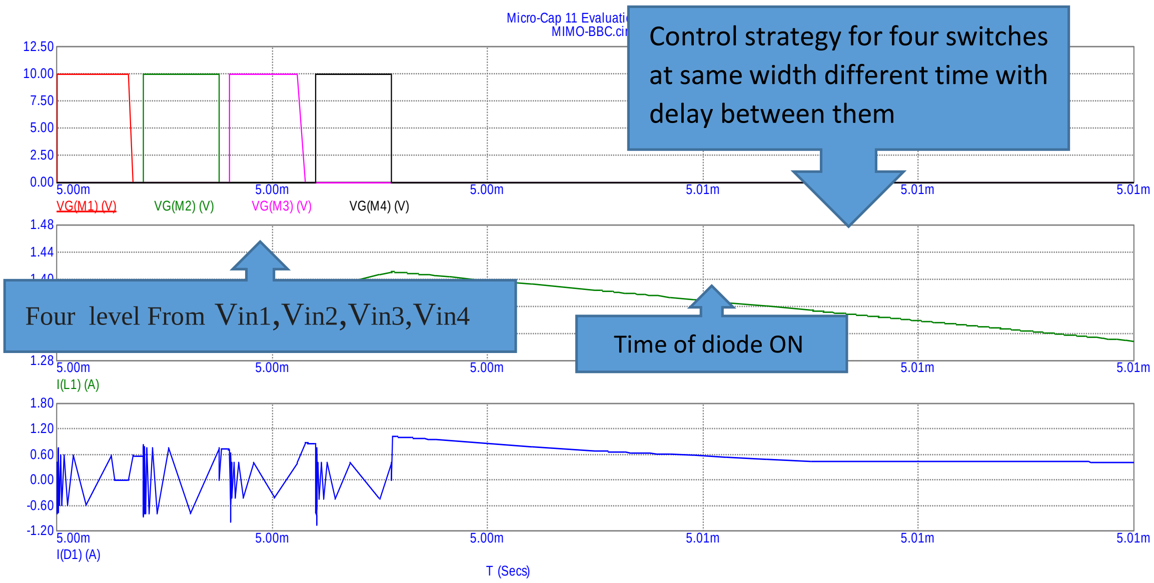

Figure 3. 7: Four level strategy control type 2 , IL1 and D1 current

In this method, we noticed that the stress on the switches will be reduced and also the number of the harmonics will be reduced too (Behjati and Davoudi, 2013).

3.3 Conclusion

In this chapter the following topics was covered

- Power electronics circuit type of MIMO-BBC is Built
- To increase the reliability of the circuit Diode Reliability is added
- Two types of Control Strategy are studied
- The floating-point problem is solved by choosing an appropriate control strategy

CHAPTER 4

DETERMINE ELEMENTS VALUE OF MIMO-BBC

4.1 Introduction

The first step to calculate the values of the elements is to determine the specifications of the proposed circuit. In the following table we listed out the parameters used in the simulations of this chapter. The aim of this chapter is to determine

- The value of all inductors and capacitor to be used.
- The ratings of the power MOSFET and the diodes to be used.

Table 4 .1: Design data 1

V input	I input	Branch1	Branch2	Branch	Ripple
12 Vdc	5.12A	3VDC	12VDC	24VDC	0,150,50 mv respectively

Table 4. 2: Design data 2

Time switching	Switch frequency	Duty cycle Branch1	Duty cycle Branch2	Duty cycle Branch 3
10uS	100KHz	0.7 uS	5 uS	7 uS

Table 4 .3: Design data 3

Iout 1 BRANCH 1	Iout 2 BRANCH 2	Iout 3 BRANCH 3	Iin 1 BRANCH 1	Iin 2 BRANCH 2	Iin 3 BRANCH 3
500mA	1.00A	2.00A	120mA	1.00A	4.00A

4.2.1 Design branch 1

4.2.1.1 Calculate the required inductor

Input inductor L_1 and L_9 can be calculated by the use of equation (2.10) and (2.12). To guarantees continuous mode operation we have

$L_9 > \frac{VOUT}{2Ioutf}$, ⟹ $L_9 > 30uH$, That to guarantee operate in continuous mode.

$L_1 > \frac{Vin}{2Iinf}$, ⟹ (L_1=L_2=L_3=L_4 and equal) and all >495uF.

This choice to gurantee continuous mode operation for L_1, and that is possible when I_{in} and I_{out} and f are large enough (Baylor, 2017).

4.2.1.2 Calculate the required capacitors

From the following equation

$$\Delta V_{out\ 1} = \frac{Iout\ 1}{c * f} \tag{4.1}$$

The ripple V_{ripple} will decreases when C and f are increase, then we can choose C_1 = 500uF and C_2 = 500uF.
Since the amount of variable voltage in the load " V_{ripple} " is related to the importance of the application, increasing the capacity of the capacitor is expensive, therefore, if the application is not critical, capacitors with a lower capacity can be used then the result of the previous equation, 100uF is enough.

Figure 4.1 and Figure 4.2 show that the output 1 voltage simulator for a range of capacitor C1 and C2 from 50uF to 1000uF at a step of 100 uF. It is noted that changes can be neglected in the case of non-critical requirements (Micrpship, 2017).

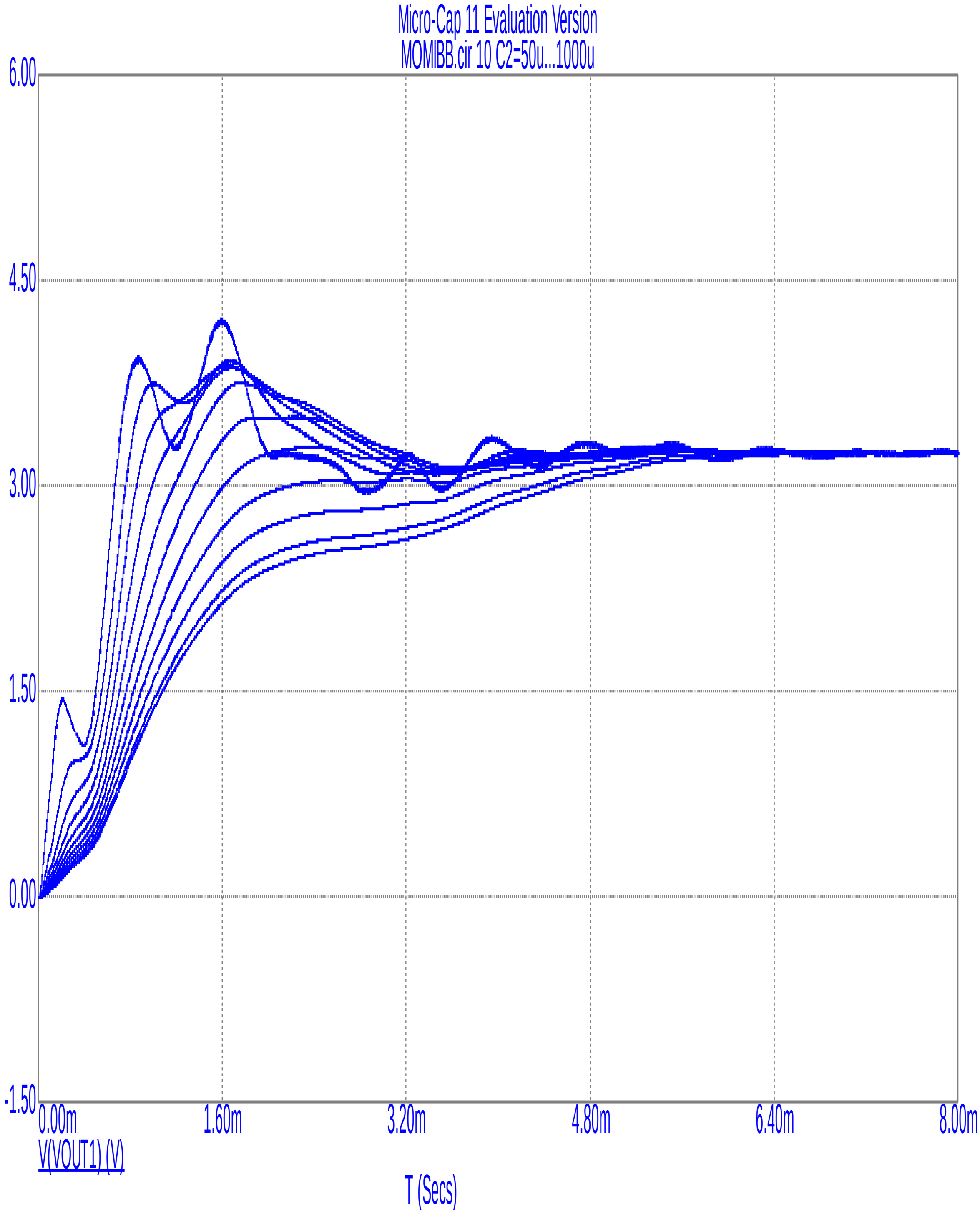

Figure 4.1: Voutput 1 when change value of C2 from 50uF to 1000uF

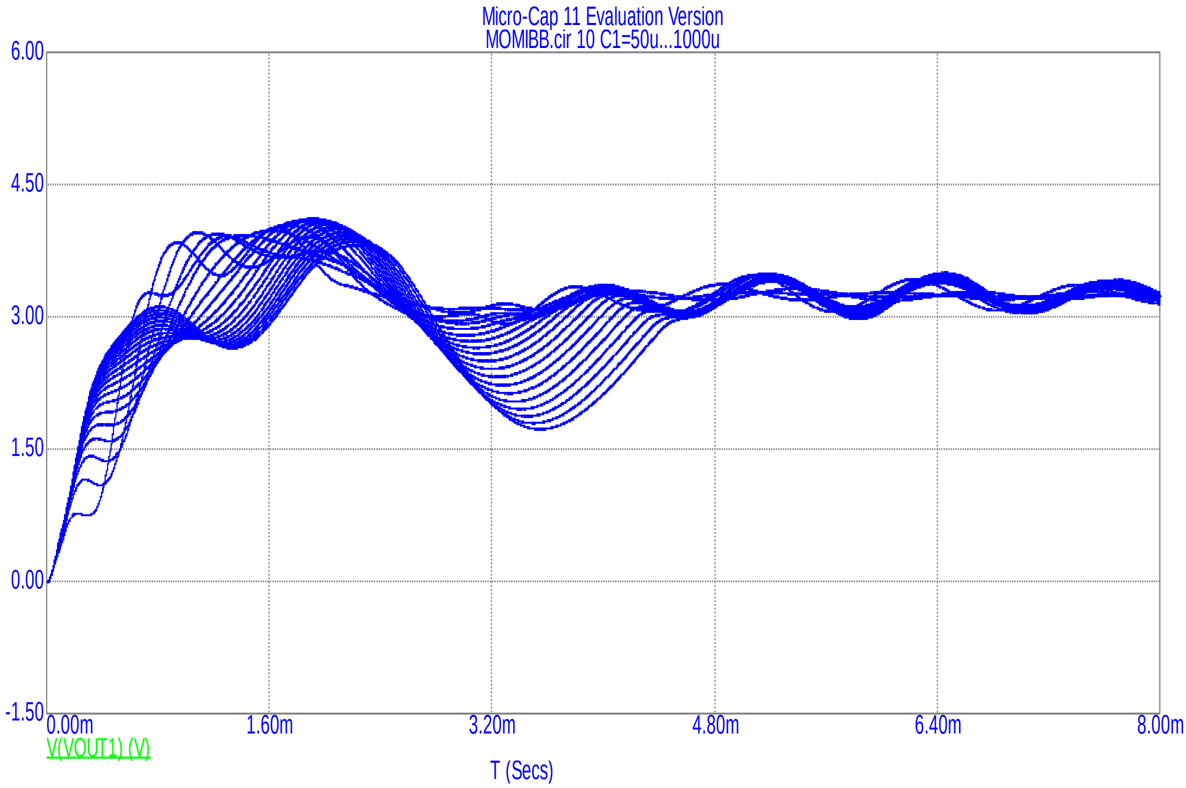

Figure 4.2: Voutput 1 when the change value of C1 from 50uF to 1000uF

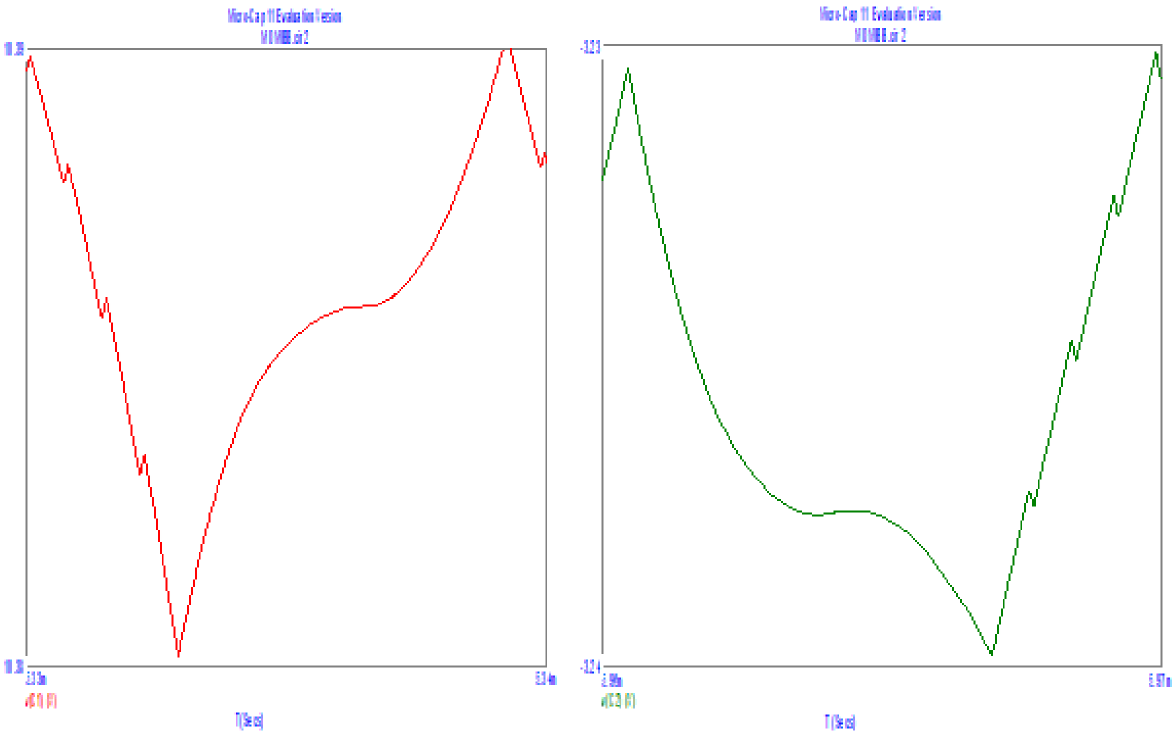

Figure 4.3: Simulate Vripple across C1 and C2

4.2.2 Design branch 2

4.2.2.1 Calculate the required inductor

Input inductors L7 and L8 can be calculated by the use of equation (2.10), (2.12). To guarantees continuous mode operation we have

$$L_7 > \frac{Vin}{2Iinf}, \Rightarrow L_7 > 60uH.$$

$$L_8 > \frac{VOUT}{2Ioutf}, \Rightarrow L_8 > 60uH.$$

To guarantee continuous mode operation, I_{in}, I_{out} and f should be large enough. For easinies choose $L_7 = L_8$.

4.2.2.2 Calculate the required capacitors

From equation (3.1) gives the ripple voltage V_{ripple}, decreases when C and f are increase, using the equation we have

$\Delta V_{out\,2} = \frac{Iout\ 2}{c*f}$, $\Rightarrow$ Solve for C_3 we have: $C_3 = 66.$ uF and $C_4 = 66.$ uF.

Since the amount of variable voltage in the load " Vripple " is related to the importance of the application, increasing the capacity of the capacitor is expensive, therefore, if the application is not critical, capacitors with a lower capacity can be used then the result of the previous equation, 100uF enough. Figure 4.4 shows simulate output 2 voltage for a range of capacitor C3 and C4 from 50uF to 600uF at a step of 100 uF

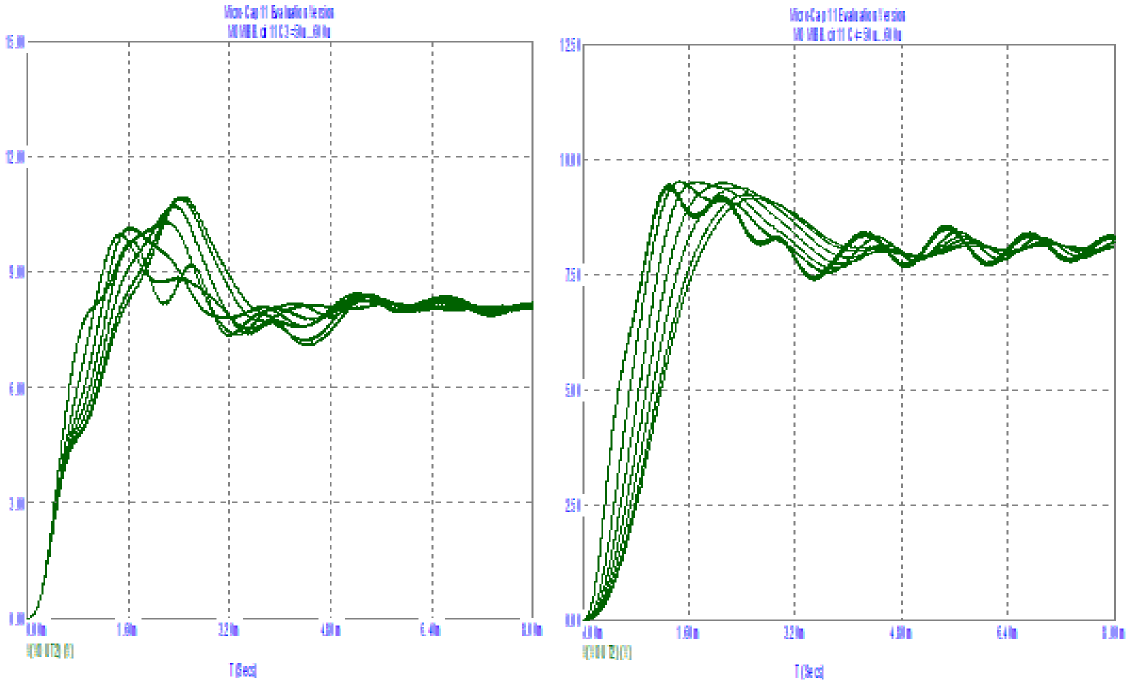

Figure 4.4: Output 2 voltage simulator for capacitors C3 and C4

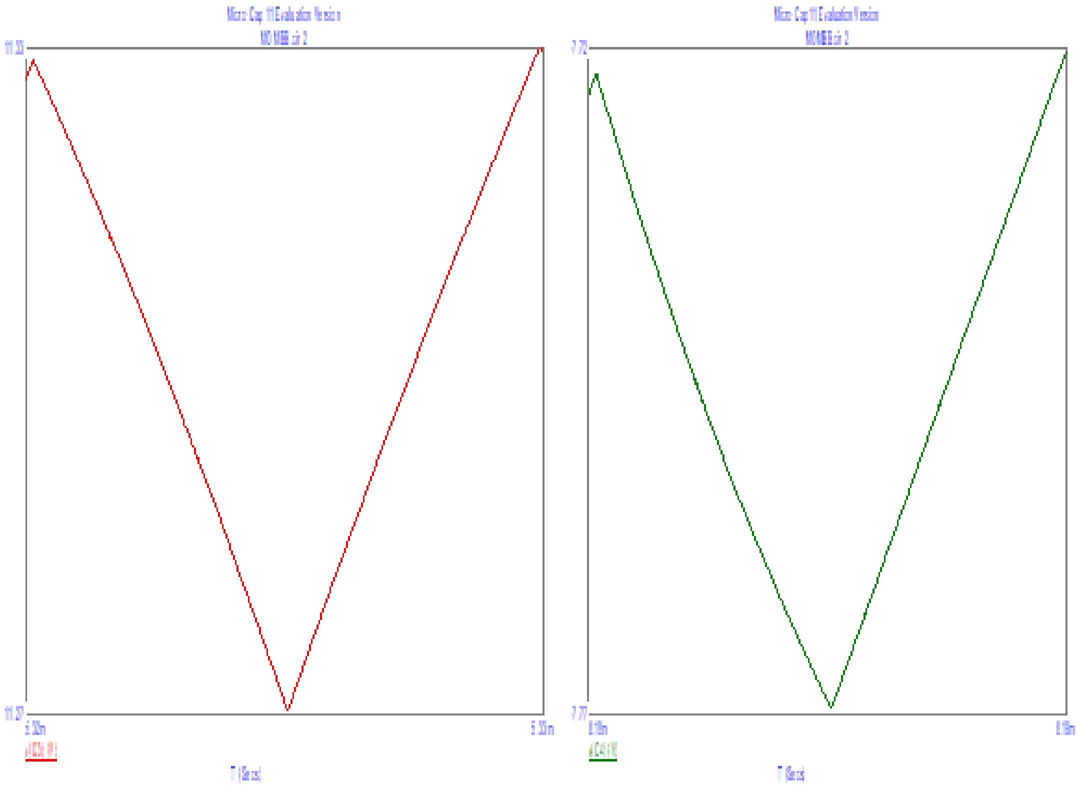

Figure 4.5: Vripple across C3 and C4

4.2.3 Design branch 3

4.2.3.1 Calculate the required inductor

The input inductors L5 and L6 can calculated by the use of equation (2.10) and (2.12). To guarantees continuous mode operation we have

$L5 > \frac{Vin}{2Iinf}$, $\Longrightarrow$ L5 > 15uH.

$L6 > \frac{VOUT}{2Ioutf}$, $\Longrightarrow$ L6 > 60uH.

and when Iin and Iout and f are large enough.

4.2.3.2 Calculate the required capacitors

From equation (3.1), the voltage ripple V_{ripple} decreases when C and f increase. Then we have $\Delta V_{out\ 3} = \frac{Iout\ 3}{c*f}$, $\Longrightarrow$ Solve for C5 we have ; C5 = 400uF and also C6 = 400uF.

The amount of the V_{ripple} voltage in the load is related to the importance of the application, and increasing the capacity of the capacitor is expensive, therefore, if the application is not critical, capacitors with a lower capacity can be used than the result of the previous equation, 100uF enough. Figure 4.6 show that the output 3 simulate the voltage for a range of capacitor C5 and C6 from 50uF to 600uF at a step of 100 uF.

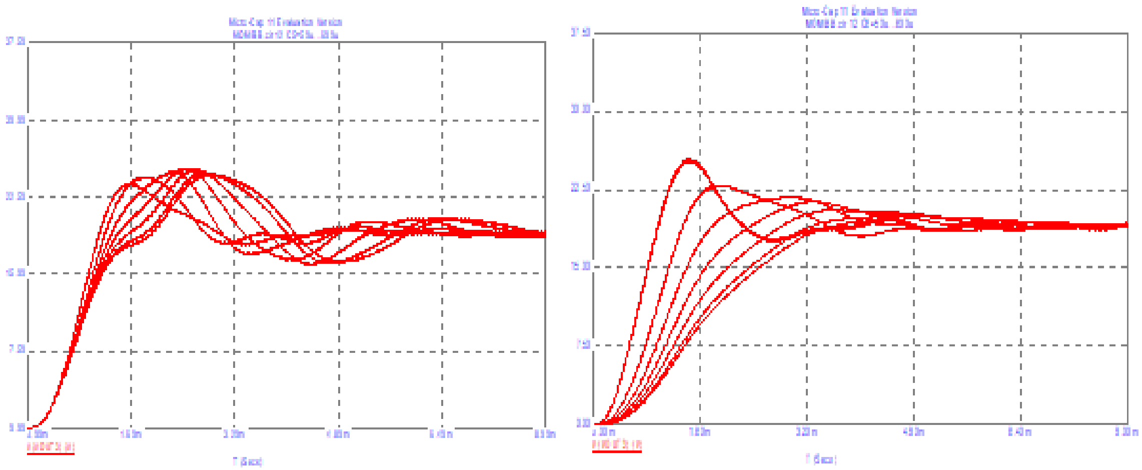

Figure 4.6: Simulate C5 , C6

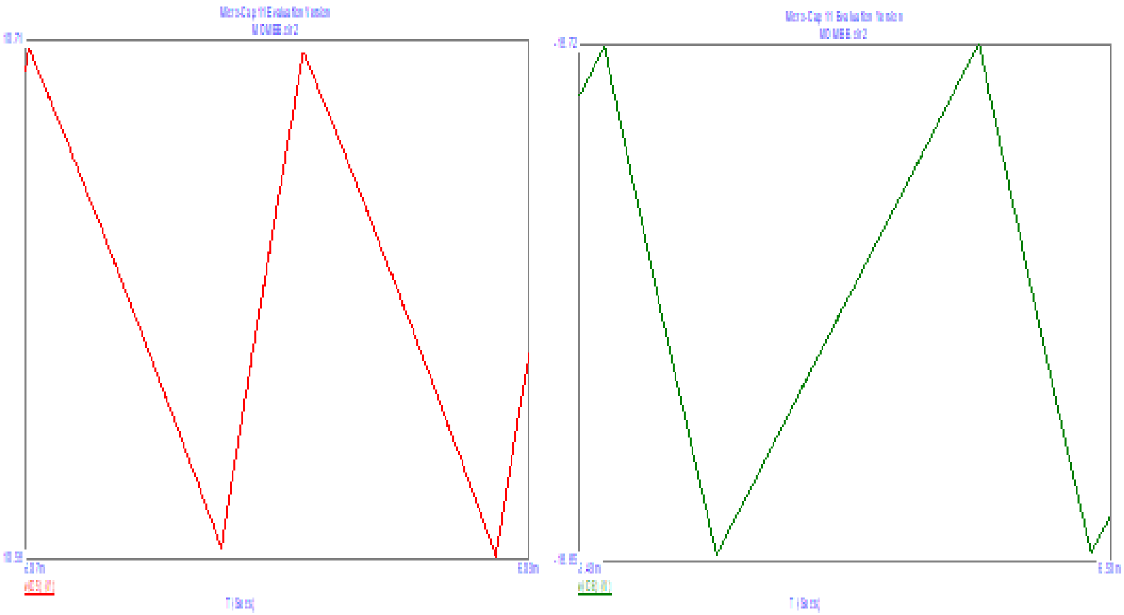

Figure 4.7: Can see the Vripple across C5 equal Vripple across C6

4.2.3.3 Diodes rating

When selecting the appropriate diode or power MOSFET there are many specifications provided by the vendors, there are some specifications which are not given in the data sheet of the element, but these specification can be calculated from the mathematical mode of the element. In general appropriate diode or MOSFET should have the following specifications:

- Rated current is one and a half times larger than the output current
- Rated voltage is one and a half times larger than the output voltage
- Quick response to both close and open situations
- Small forward diode resistance in order to reduces power loss
- Large reverse diode resistance
- High enough peak reverse voltage
- Fast closing and opening time of the MOSEFET (T_{rise} and T_{fall})
- Drain-source resistance R_{DS}

Considering the above specification, the parameters of the used diodes and power MOSFET are listed in the following Tables.

Table 4 .1: Specification of the diodes

	V	I	P	V_R	RF
D1,2,3,4	12	2	3	MΩ	Small
D5,6	25	3	25	MΩ	Small

Table 4 .2: Specification of the MOSFET transistor

V	I	P	V_R	Trise	Tfall	F_T
25	3	10	MΩ	50ns	50ns	1MHz
80	4	10	MΩ	50ns	50ns	1MHz

CHAPTER 5

MICRO CAP 11 SIMULATION RESULT

5.1 Introduction

In this chapter the circuit will execute to achieve the following point:

- Simulate steady state
- Simulate inductors to study and guarantee Continuous Operation Mode
- Simulate the effect vary of R Load on three branches
- Determine all voltage node and all current branches
- Measurement V ripple at three stage outputs
- Simulate effect vary capacitors on circuit behavior

In the simulations we used MICRO CAP 11 electronics simulation program (Spectrum-Soft, 2012). The suggested circuit diagram is shown in Figure 5.1 where we have four sources as inputs $V_{in1} = V_{in2} = V_{in3} = V_{in4} = 12V_{DC}$, and there are six sources which are used to generate pulses to control strategy mode 2 (V_1, V_2, V_3, and V_4) and to feed gates for six MOSEFET. Additionally, we have three terminals as outputs in addition to four protection diodes connected to all voltage sources as series.

Input currents feeds three stages output (branch 1, branch 2, and branch 3) after passing through the fuse resistor R

$$I_{in,\text{TOTAL (FROM ALL SOURCES)}} = I_{R\ \text{(FUSE RESISTOR)}} = I_{in1} + I_{in2} + I_{in3} + I_{in4} \tag{5.1}$$

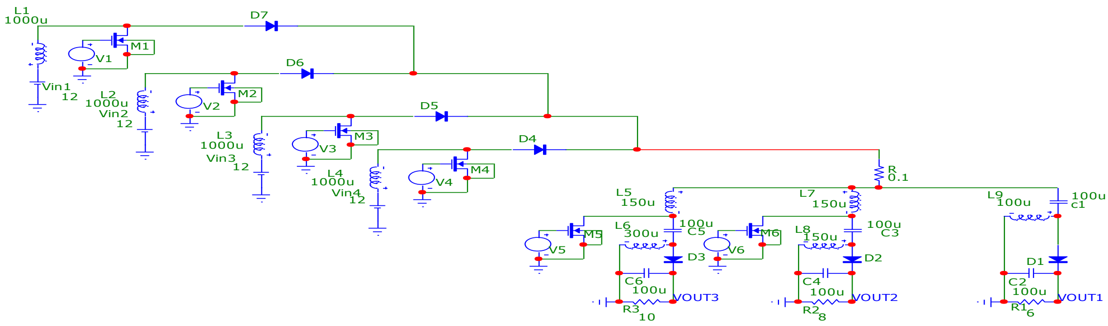

Figure 5.1: Circuit diagram was built by MICRO CAP 11

5.2 Steady State Analysis

In this analysis, it is assumed that the source of the DC voltage is coming from solar roofs PV arrays or batteries (Kumar and Jain, 2013). Furthermore, it is assumed that all input voltage are equal, " Vin1 = Vin2 = Vin3 = Vin4 =12VDC and the goal is to operate the circuit in continuous mode operation.

Steady state is starting when circuit passed the transient case. The transient case happens at initial operating moments where t = 0^+. Figure 5.2 shows outputs voltages at first 100us where output 1 (branch 1) cannot reached up 600mv, output 2 (branch 2) and output 3 (branch 3) are still not reached up 160mv. This work does not interest to the study in this work .

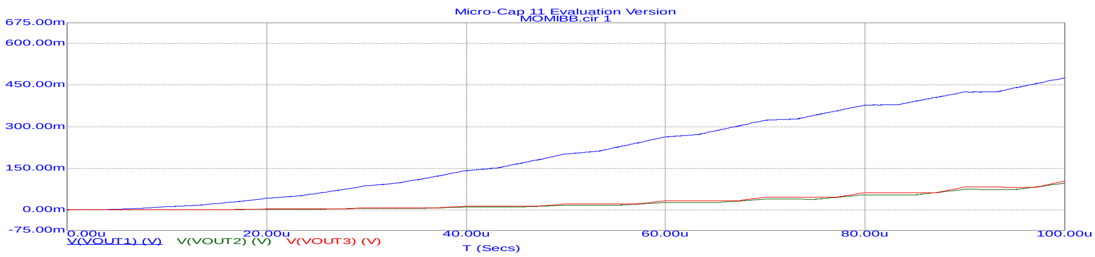

Figure 5.2: Voutput 1 , Voutput 2 and Voutput 3 at transient case before 100us

5.3 Continuous Mode Operation

Good parameters of the power electronics have smaller size and smaller weight. This can be achieved by operating the circuit in the continuous mode (Dobbs and Chapman, 2003) and to accomplish this, the values of L1, L2 must be selected according to the equations (5.1) and (5.2) as

$$L_{1,2,3,4} > \frac{Vin}{2Iinf} \tag{5.1}$$

$$L_9 > \frac{VOUT}{2Ioutf} \tag{5.2}$$

5.4 Guarantee Continuous Mode by L9 Value

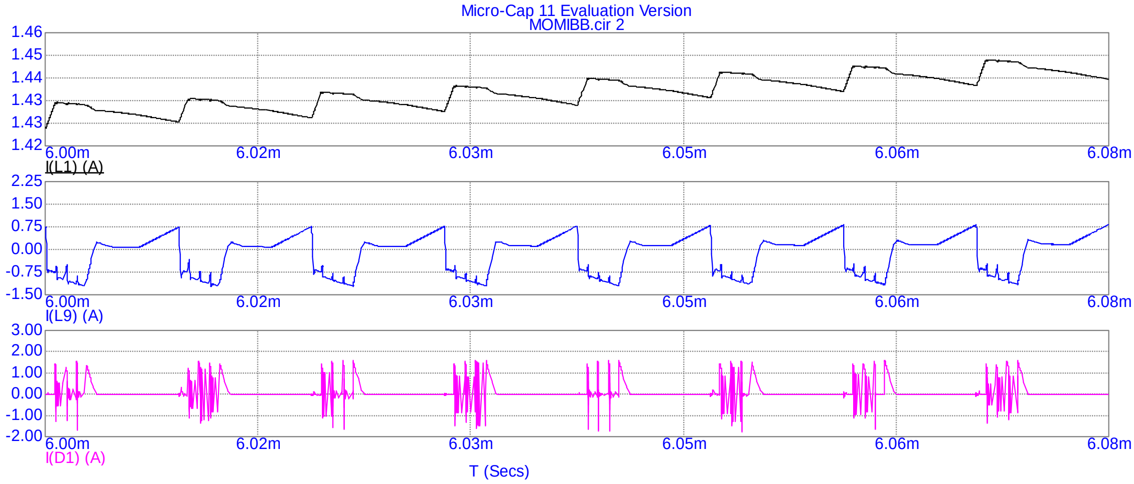

Figure 5.3: IL1, ID1 and IL9, where L9 = 1uH

Figure 5.3 IL1curve is approaching zero, that means the circuit doesn't work in continuous mode when L9 =1uH.

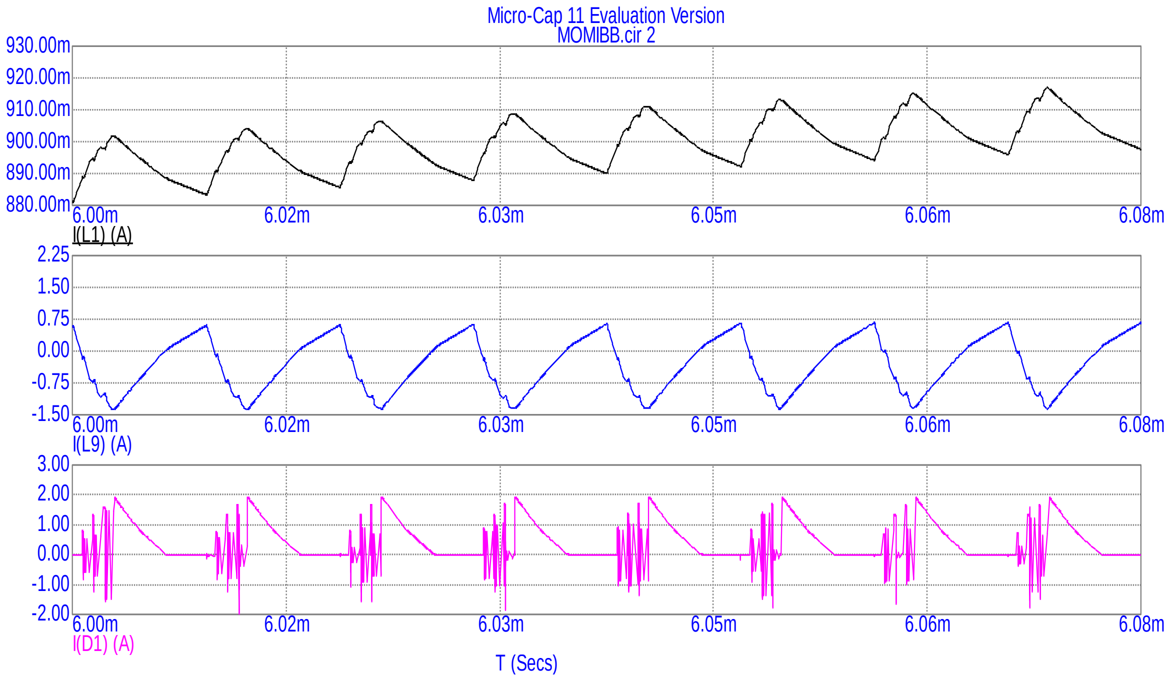

Figure 5.4: IL1, ID1 and IL9, IL9=10uH the curve is moving away from zero

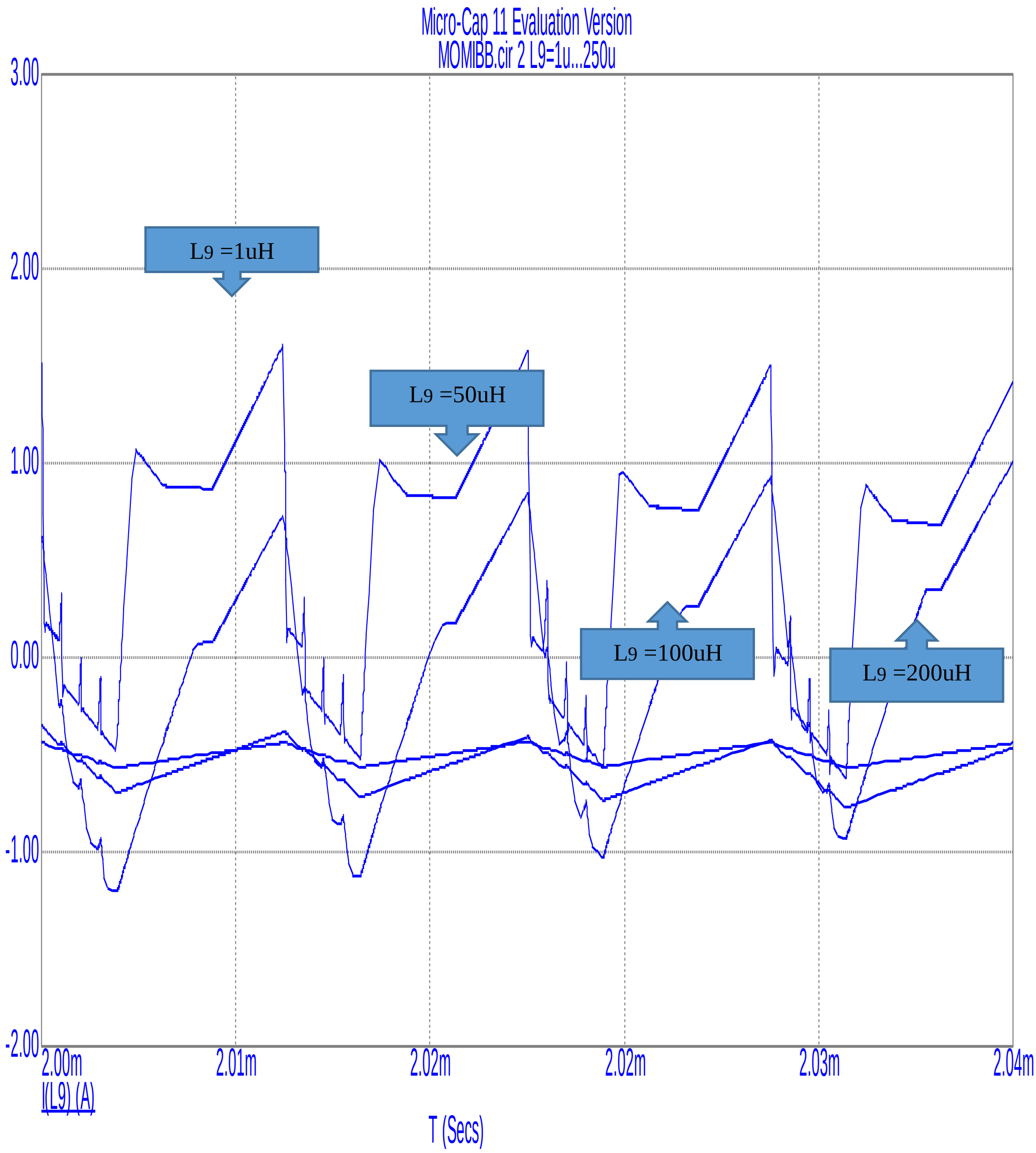

Figure 5.5: IL9 , can see the curve is moving away from zero

Similarly, Figure 5.6 and Figure 5.7 show the effect of increasing or decreasing value of L_1, L_2, L_3, L_4. From there we can see that values of I_{L1}, I_{L2}, I_{L3}, I_{L4} are approaching zero or moving away from it.

Show that D_1 is opens when the circuit works in continuous mode operation and when " V_L curve is close to zero axis " Similarly, D_1 closes when circuit work in discontinuous mode operation.

5.5 Guarantee Continuous Mode by L1 Value

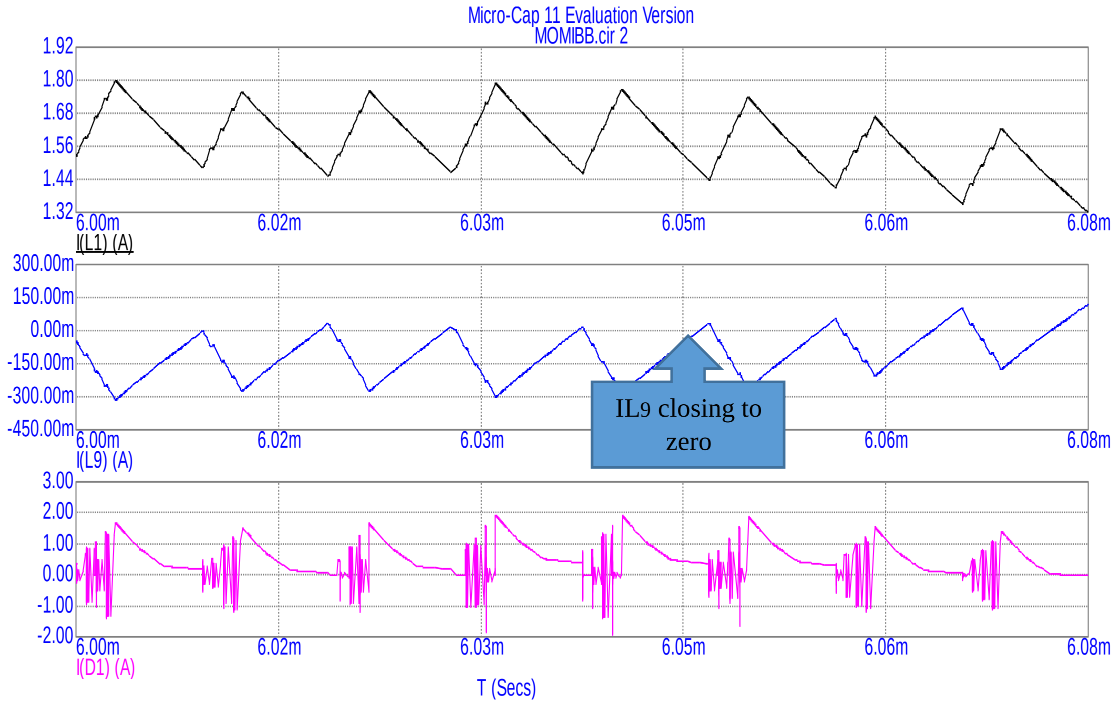

Figure 5.6: IL1,IL9 of ID1, at selected values for L1, L2, L3, L4 =100uH

Figure 5.6 shows curves of value of IL9 close to zero axis when value equal 100uH in this case the continuous mode is not being achieved.

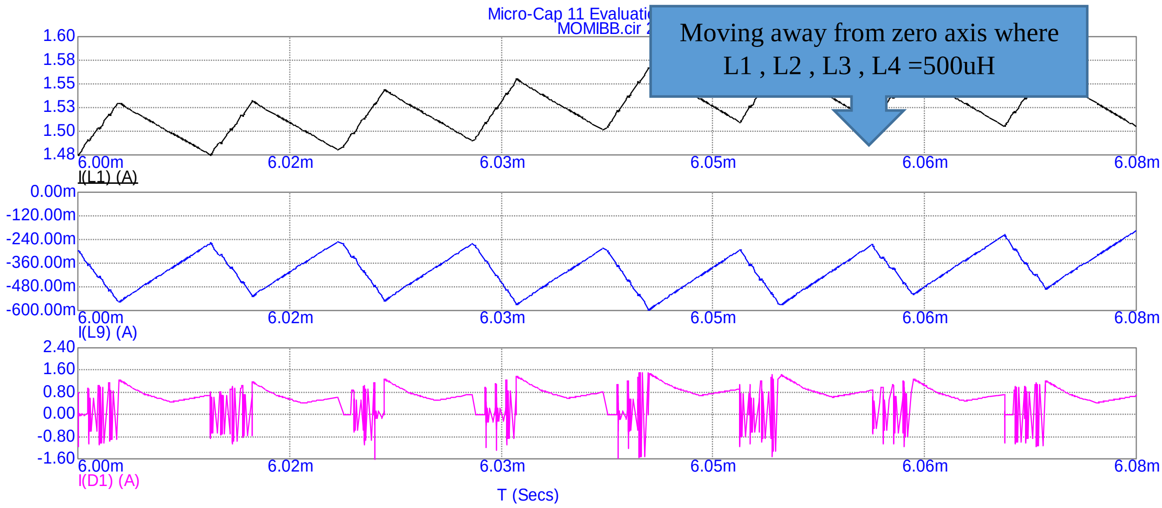

Figure 5.7: IL1,IL9 of ID1, at selected values for L1, L2, L3, L4 = 500uH

Figure 5.7 where can see curve of IL9 moving away from the zero axis when value equal 500uH in this case the circuit close to work continuous mode

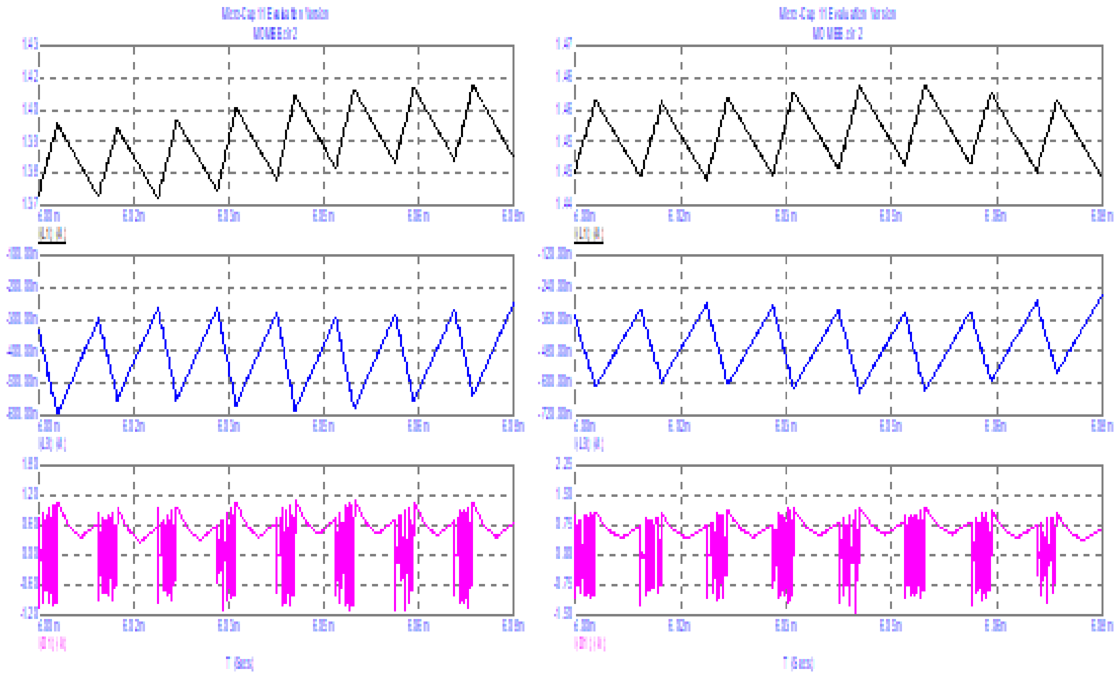

Figure 5.8: IL1,IL9 of ID1, at selected values for L1, L2, L3, L4 = 1000uH

Then 2000uH where can see curve of IL9 moving away from zero axis, in this case the circuit achieves to work in continuous mode.

5.6 Select the Values of the Elements of the Circuit

Achieve continuous operation mode, the value of components are tabulated in Table 5.1

Table 5 .1: Components Table All Inductors And Capacitors Use Micro Units

L1,2,3,4	**300uH**	**L7**	**300 uH**	**L5**	**300 uH**
L9	150 uH	L8	150 uH	L6	150 uH
R1	6Ω	R2	8 Ω	R3	10 Ω
All capacitor			100uF		
All diodes			Generic diodes		
All switches			IFR024		
All sources			12Vdc		

5.7 Control Strategy Type 2

The floating-point problem has been solved by linking one end of the capacitor C1 to the ground through both M5 and M6 that when they have ON time, so the duty cycle for each D_{Boost} and $D_{(Vo=VI)}$ always greater than the operating time switches M1, M2, M3 and M4 (Σ D_{Buck}) this control strategy appeared in Figure 5.5, control strategy type 2 generated by MICRO CAP 11, so can write:

$$\mathbf{D_{Boost}} > \mathbf{D_{(Vo\,=\,Vi)}} > \sum_{1}^{N} D_{\mathbf{BuckN}} \qquad (5.3)$$

N is the number of V_{in} sources.

Table 5 .2: Operation time for three stage outputs, Ts =10us

DM1 Buck	V DM2 Buck	DM3 Buck	DM4 Buck	DM5 Vo equal Vi	DM6 BOOST
0.7us	0.7us	0.7us	0.7us	5us	7us

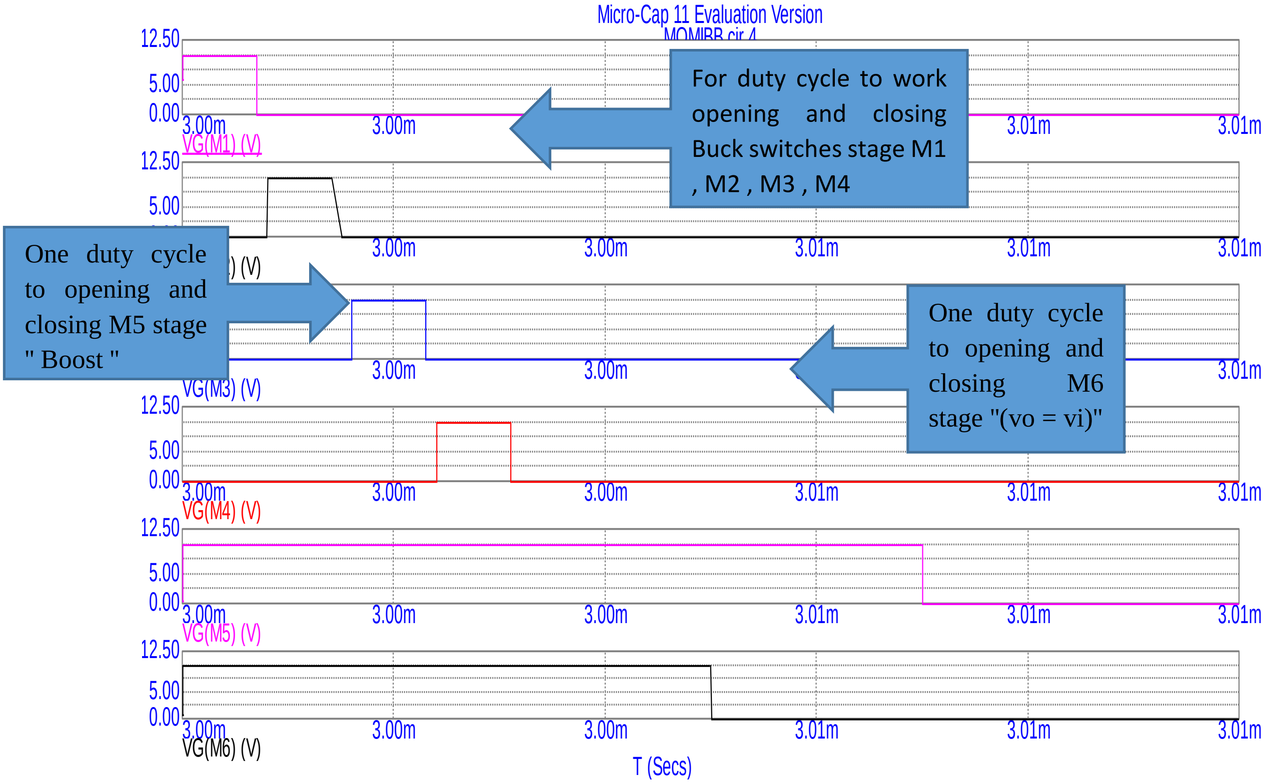

Figure 5.9 Control strategy type 2 generated by MICRO CAP 11

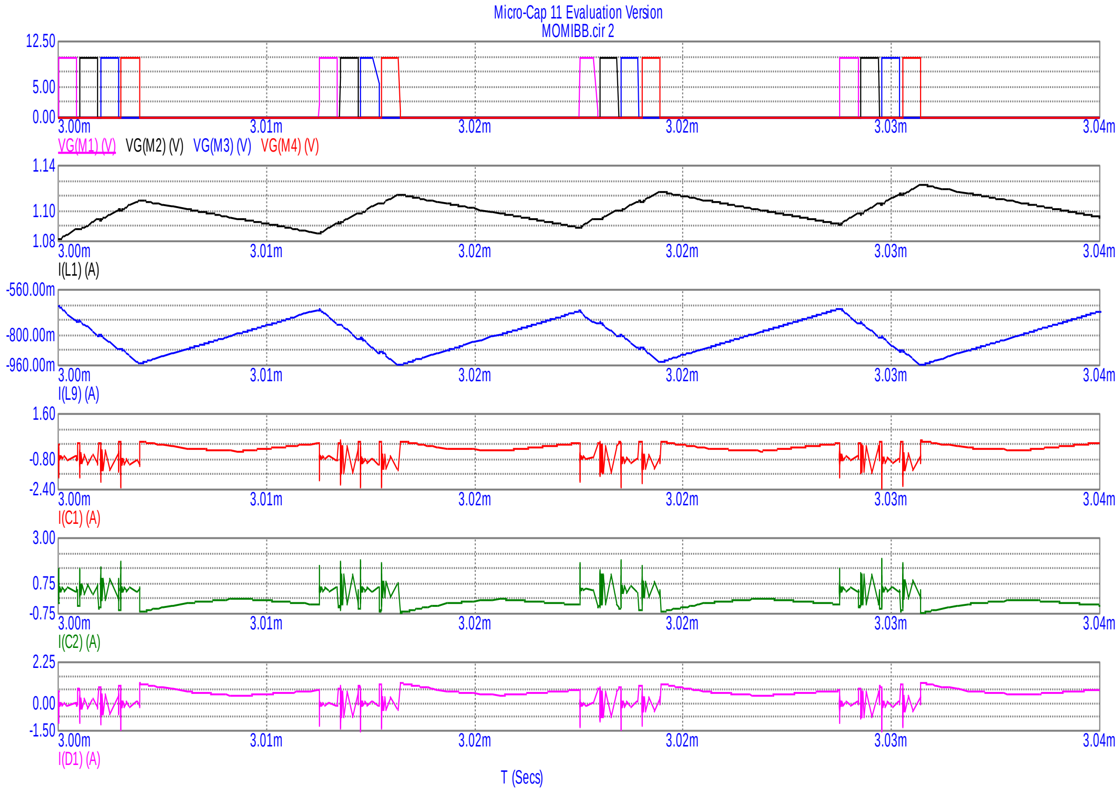

Figure 5.10: Element current for branch 1 was get by MICRO CAP 11

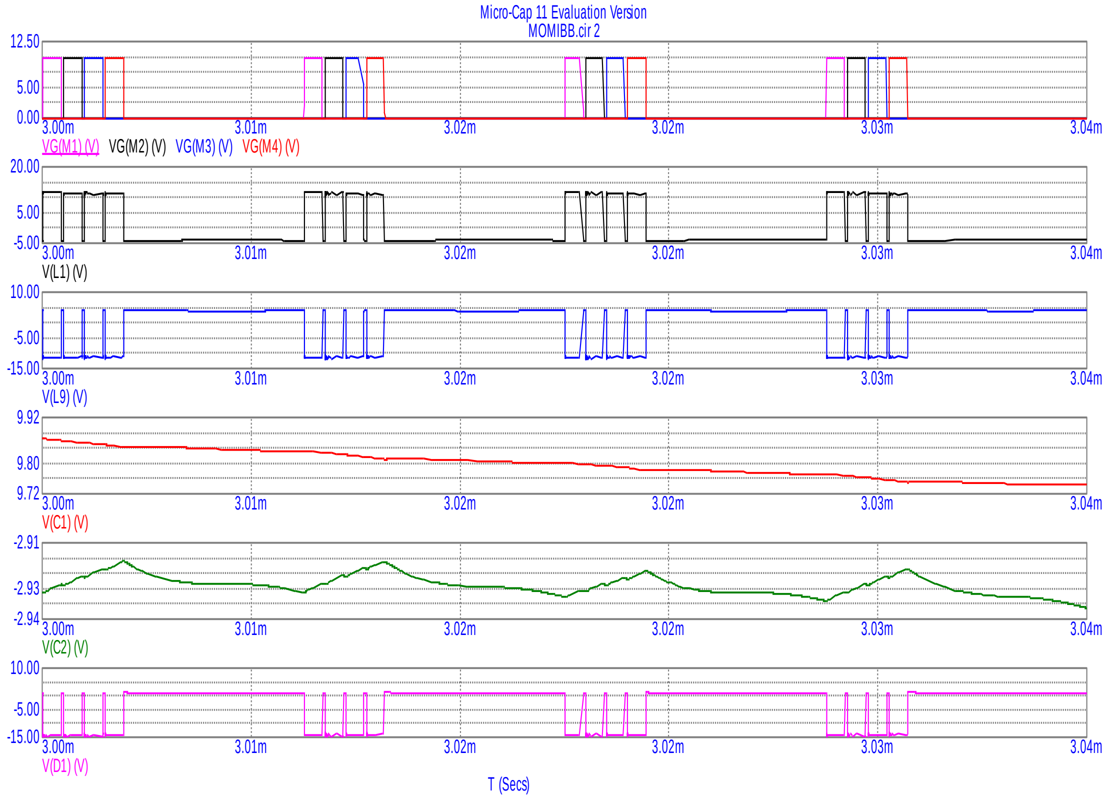

Figure 5 .11: Element's voltage for branch 1 was get by MICRO CAP 11

5.8 Voltage and Current Output

For minimum voltage ripple and to keep the output current constant, C1 and C2 must be chosen to be large enough. Figure 5.12 shows the output voltage VC1 and VC2 at steady state point. The ripple value across each capacitor is 0.01v, this ripple value is low enough for most of the applications (Rashid, 2012), (Baylor, 2017).

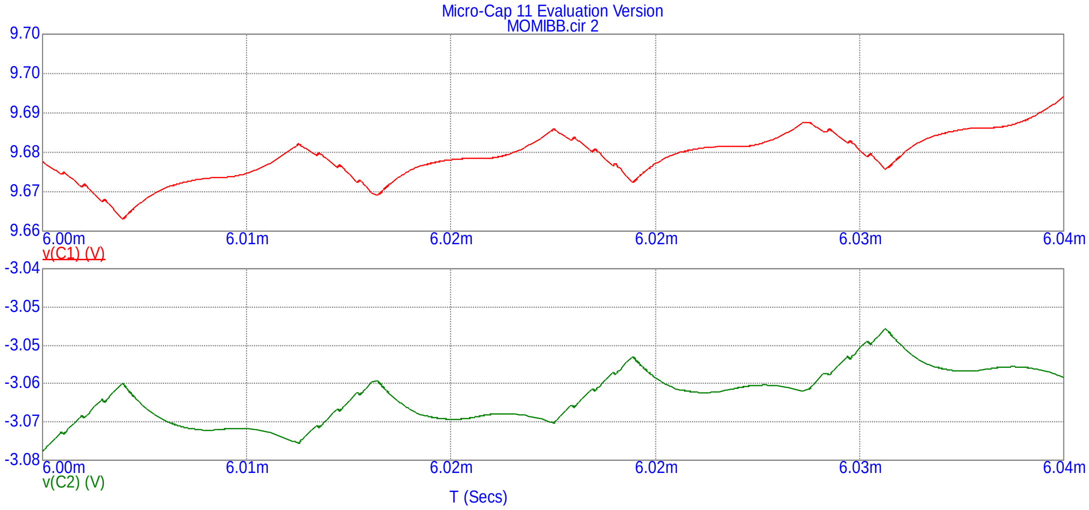

Figure 5.12: Approximately Vripple across VC1 and VC2

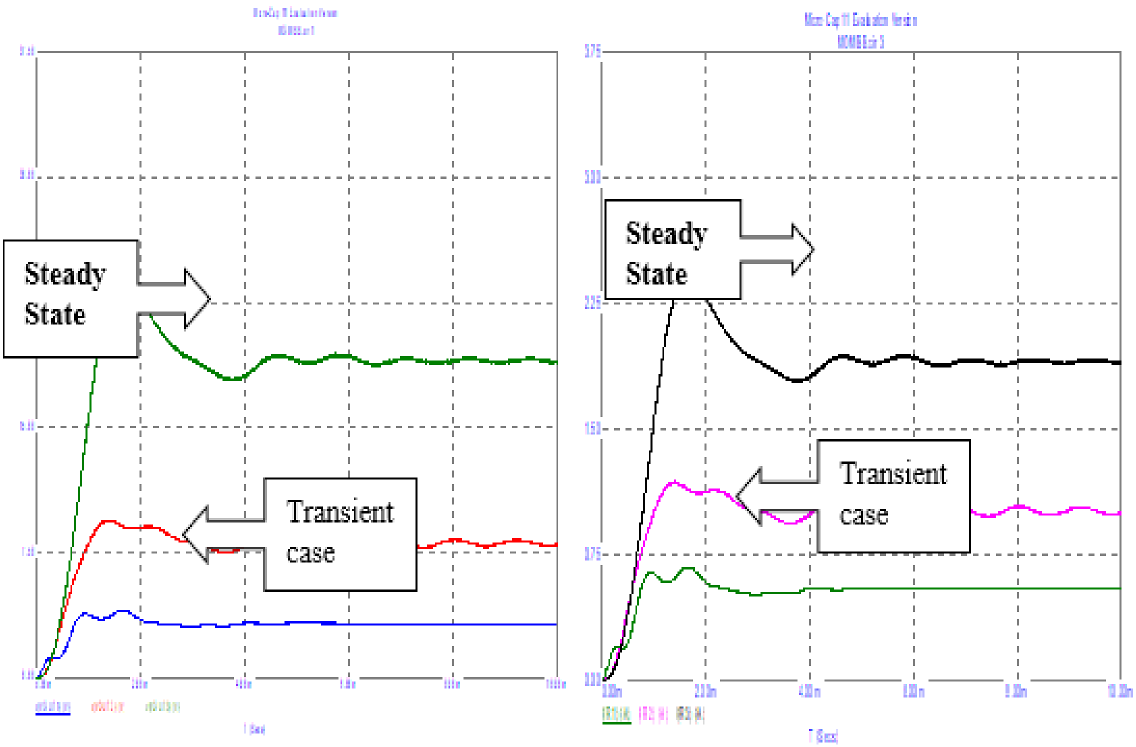

Figure 5.13**:** V outputs and I outputs

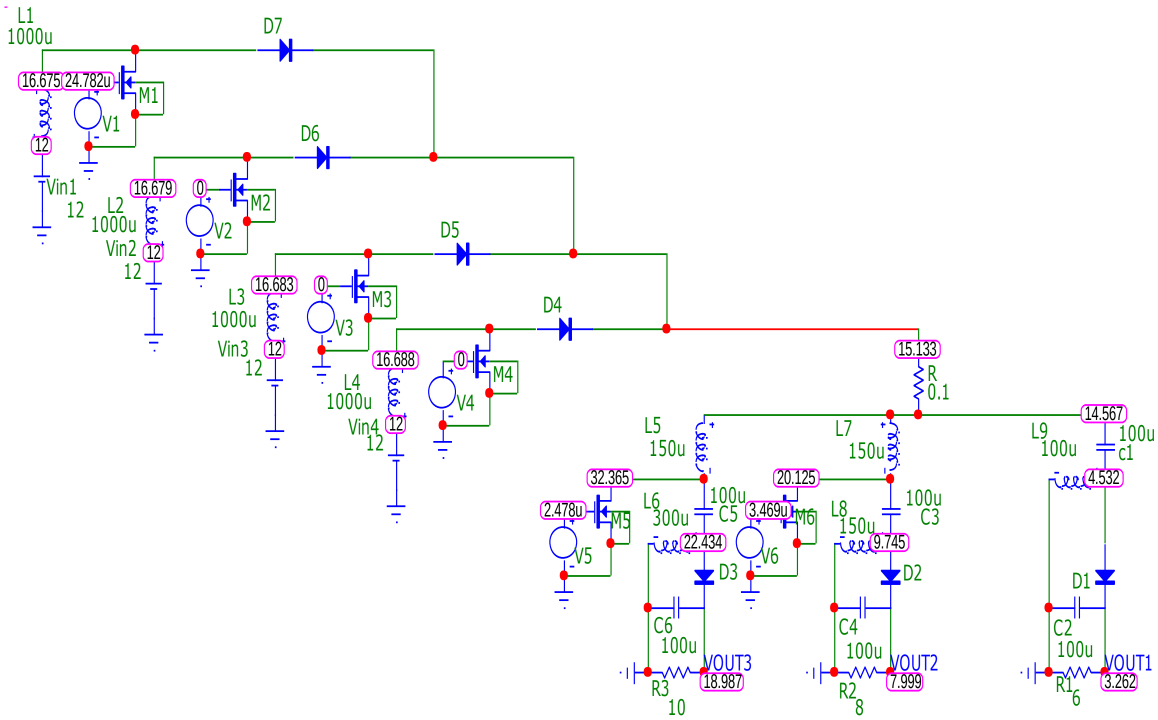

Figure 5.14: The solution for voltages at all nodes was get by Micro Cap 11

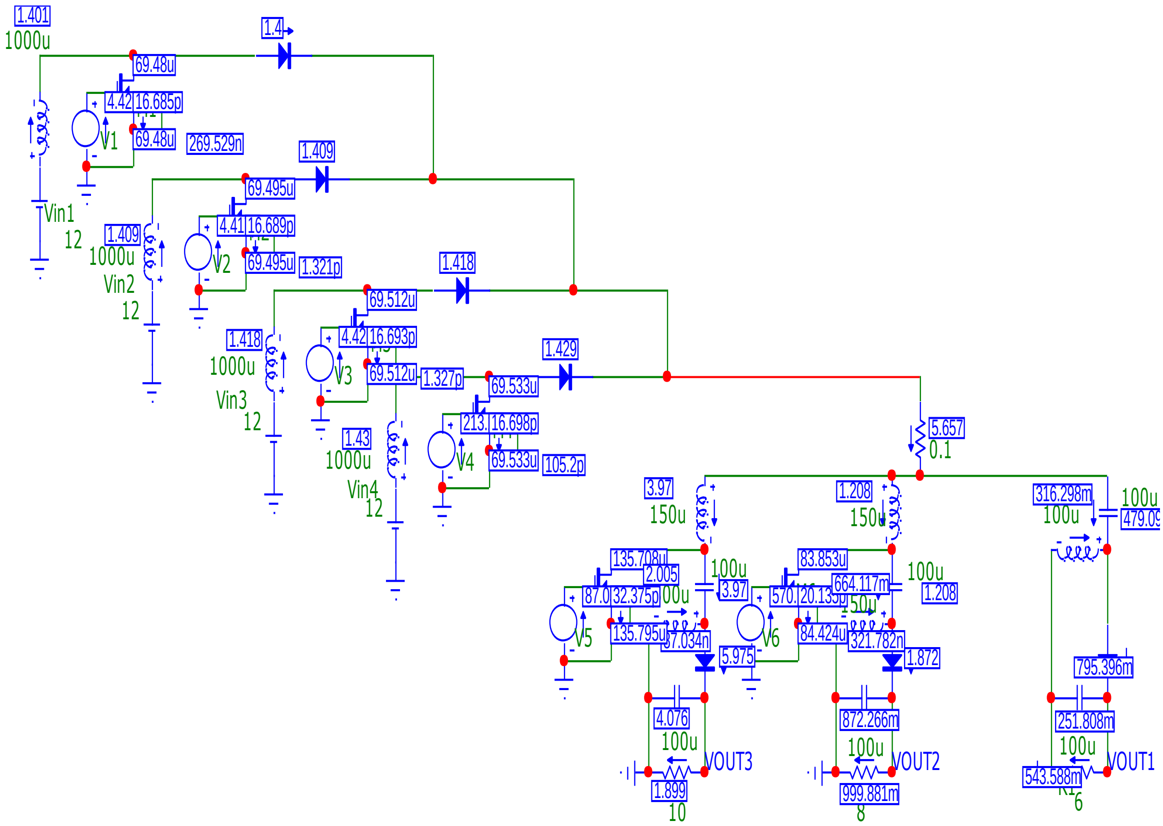

Figure 5.15: The solution for currents at all branches was get by Micro Cap 11

5.9 Load Resistance Changes and Output Voltages

Figure 5.12 shows the output voltage V_{out} for three stages outputs at different values of R, changing from 1Ω 4Ω, 7Ω and 9Ω.

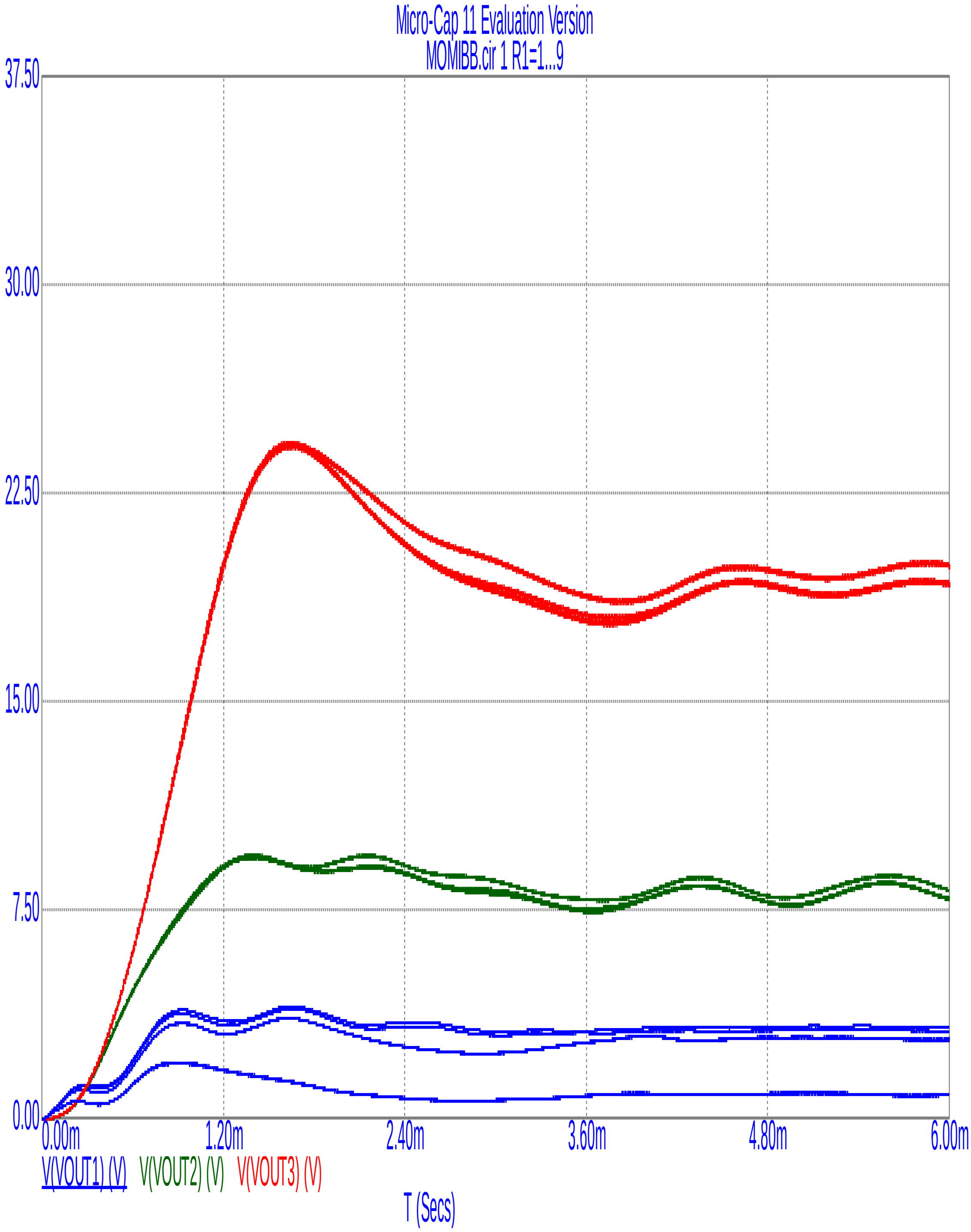

Figure 5.16: Outputs voltage at different R1, load branch 1

Branch 1: R1 and R3 are constant, and we are changing R1 as 1Ω, 4Ω, 7Ω and 9Ω .The outputs are changing for branch 1 to 0.90v,2.9V, 3.2V and 3.3V also respectively, as shown in Figure.5.13. When R1 is reduced to 1 Ω the output voltage collapse from 3V to 0.90V, conversely when R1 is increased to 9 Ω , then we notice an increase in the output voltage up to 3.3V.

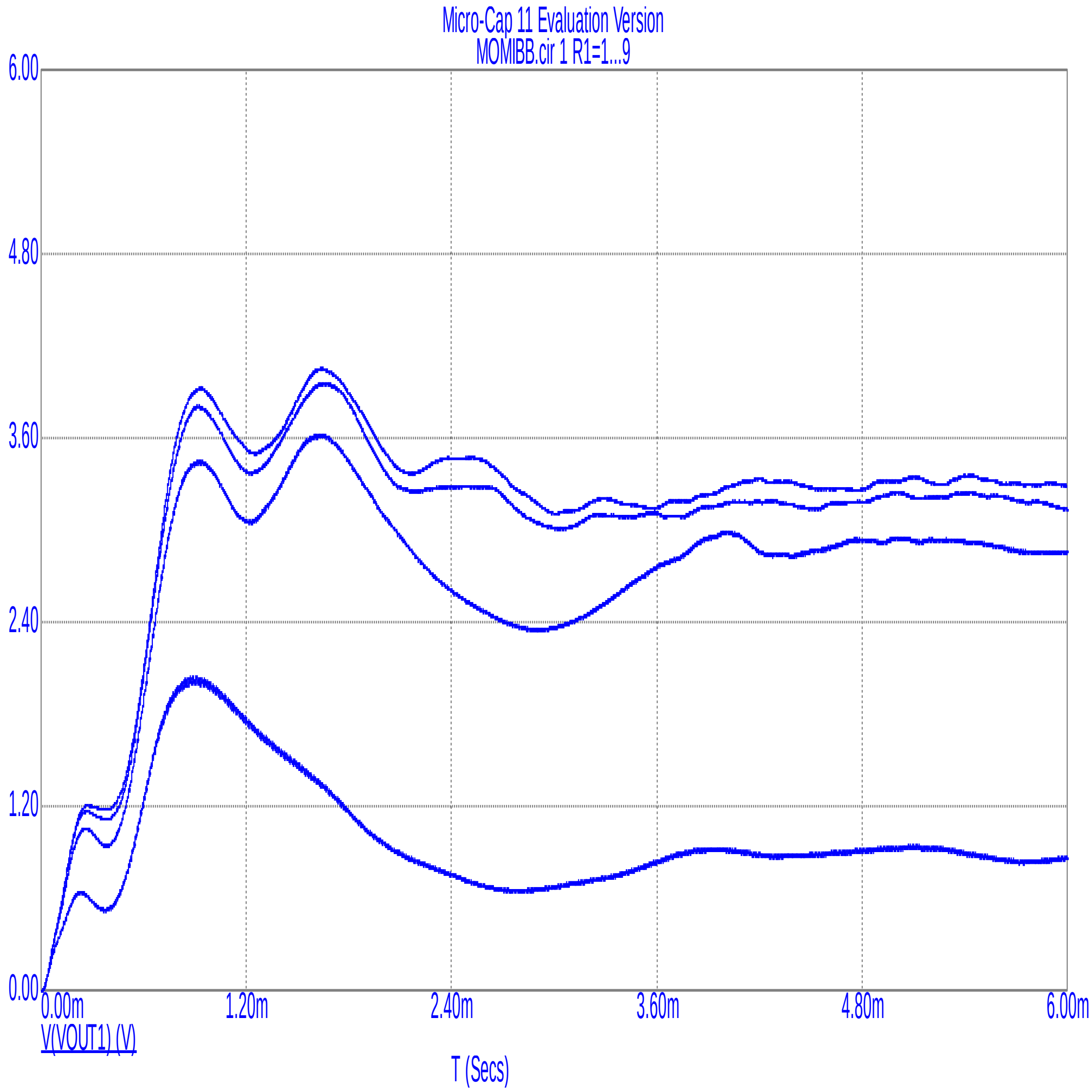

Figure 5.17: Output voltage collapse from 3V to 0.90V

Branch 2: R1 and R3 are constant, and we are changing R2 to values 4Ω, 7Ω, 10Ω, 13Ω, and 16Ω respectively. Then the outputs changes between 7.35v, and 9V, as shown in Figure.5.18. When R2 is reduced to 4 Ω the output voltage collapses. When R2 increases to 16 Ω we notice an increase in the output voltage up 9V.

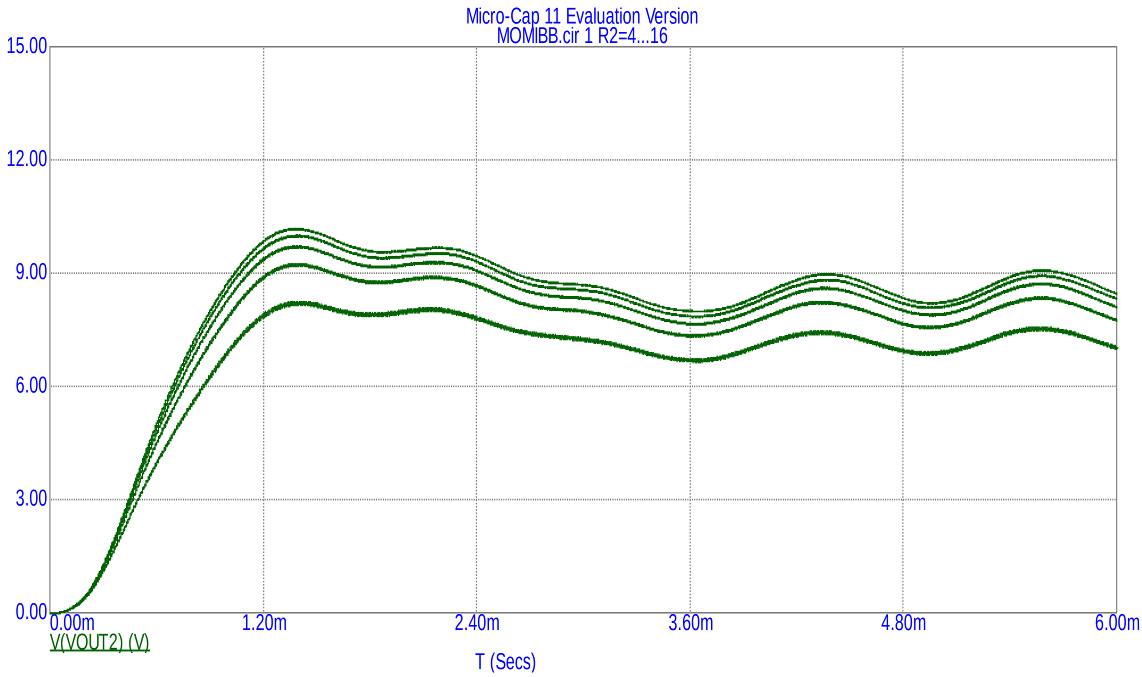

Figure 5.18: Vary voltage output 2 when reduces R2 or decrease

Branch 3: R1 and R2 are constant, and we are changing R3 to value 5Ω, 10Ω 15Ω and 20Ω respectively, Where the output voltage varies 15.85v to 21.89V as shown in Figure.5.19.

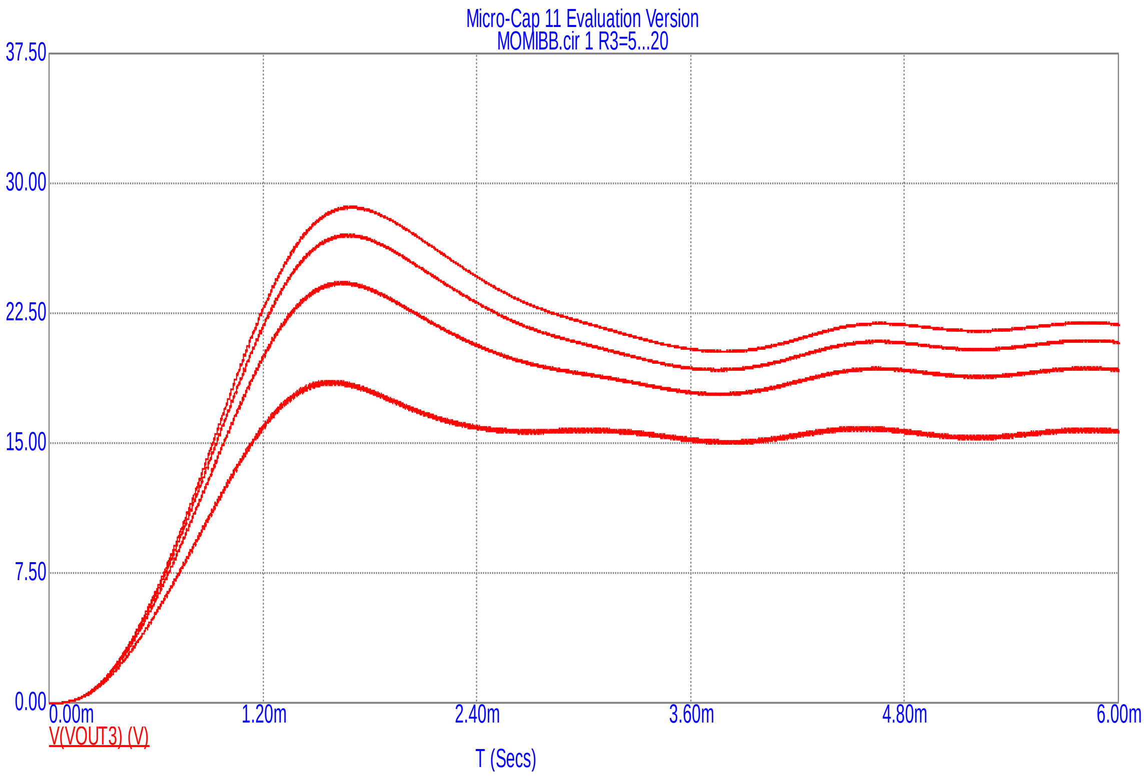

Figure 5.19: Change voltage depending on change R3

5.10 Different Between the Value of Inputs DC Sources

The MIMO-BBC in this work was designed to produce 3V,12V and 24V output voltage. That is assuming all elements are ideal and when the all DC sources are equal. But in case we have different DC input voltage sources, then we have to study and simulate this scenario. Figure 5.20 shows the simulation using Micro Cap 11 simulator when we have different DC input voltages.

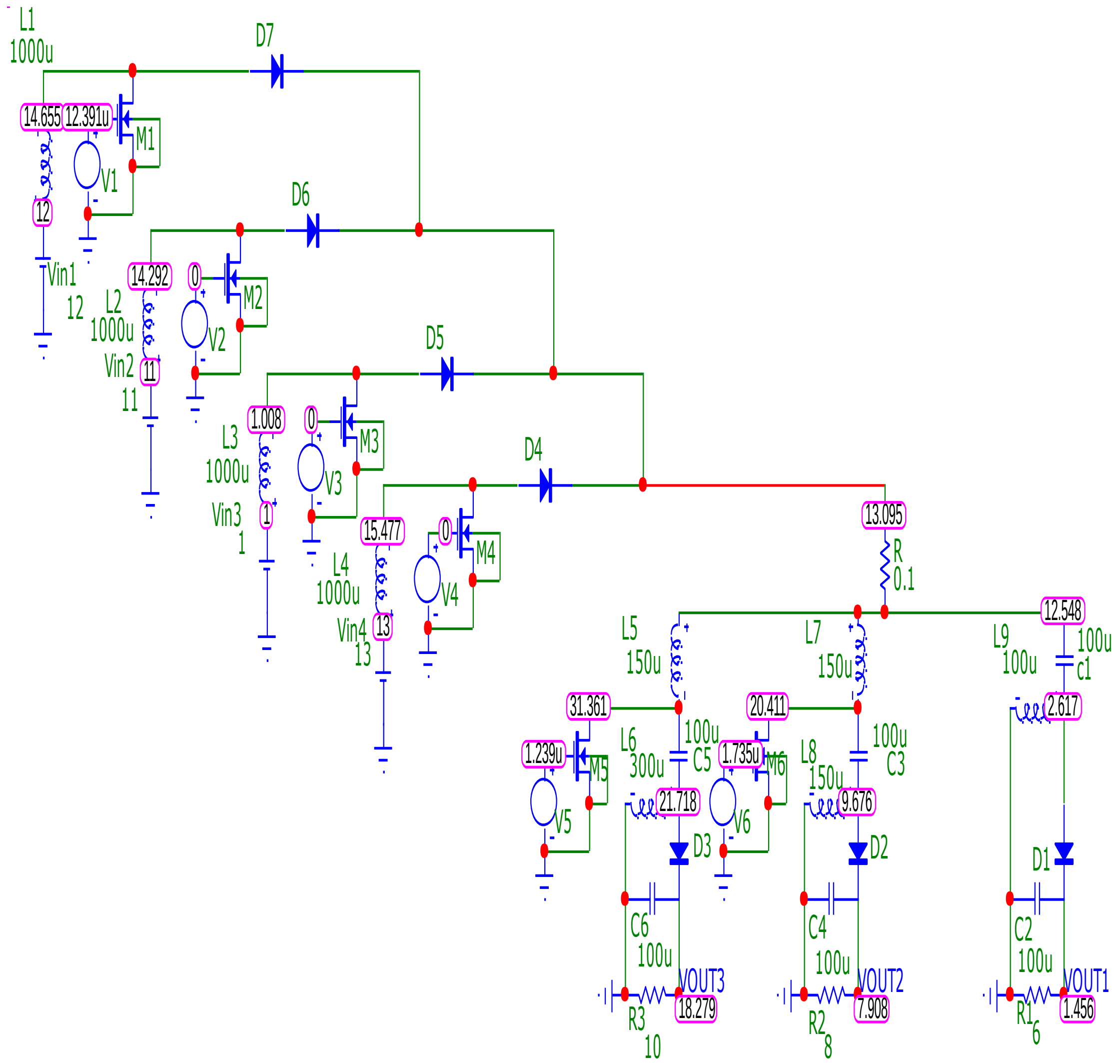

Figure 5.20: Show the value of the three output stages

The influence of using different values of DC sources is that the output 1 is decreasing, where the output 2 and output 3 are increasing. Another control circuit is added to regulate the output voltages. This circuit will control the width of the duty cycle, as shown in the block diagram Figure 5.20.

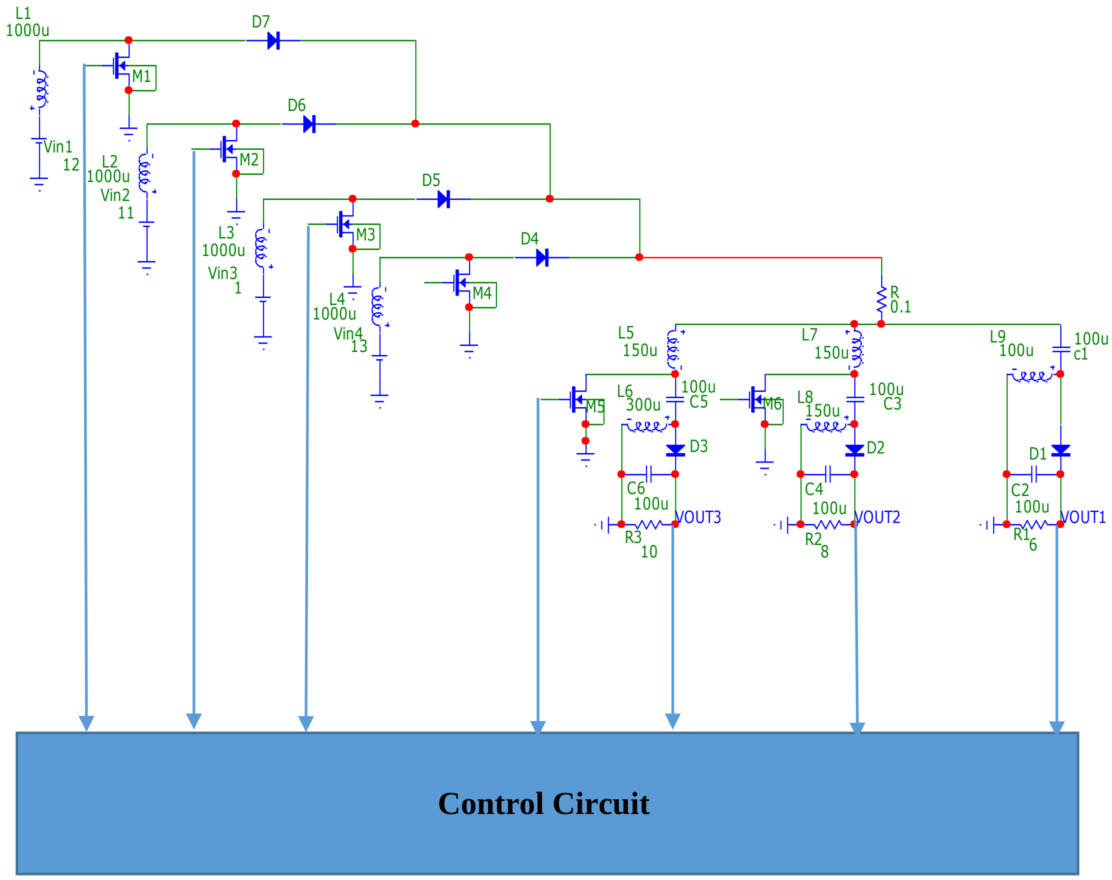

Figure 5 .21: The block diagram to suggest solution different value of inputs

5.11 Change Number of Inputs

Figure 5.22 shows a MIMO BBC when the number of inputs DC sources is increased from three inputs to four inputs. The output 1, output 2 and output 3 are shown in Figure 5.22, and the output voltage results are 2.80v, 8.20v and 19.0v respectively. Where the previous result was 2.95v, 8.16v and 19.09v respectively. A regulation circuit may be added in order to correct the error in the output voltage, the error will be used to control the duty cycle of the converter..

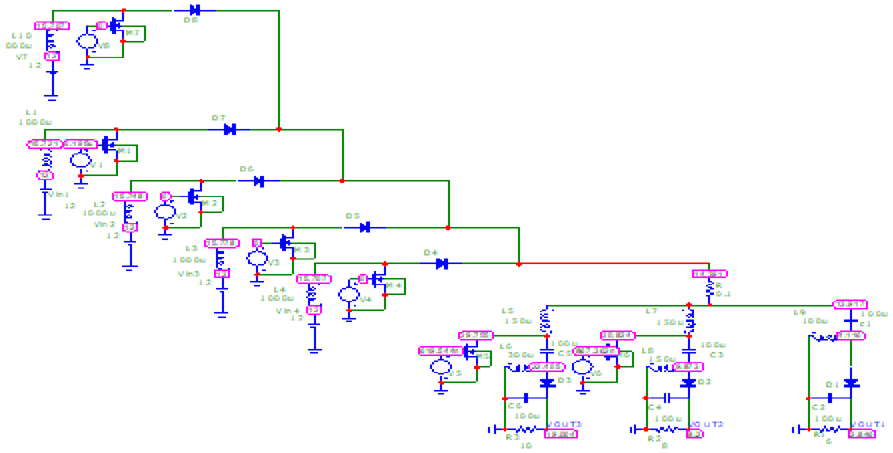

Figure 5.22: MIMO BBC when increase number of inputs

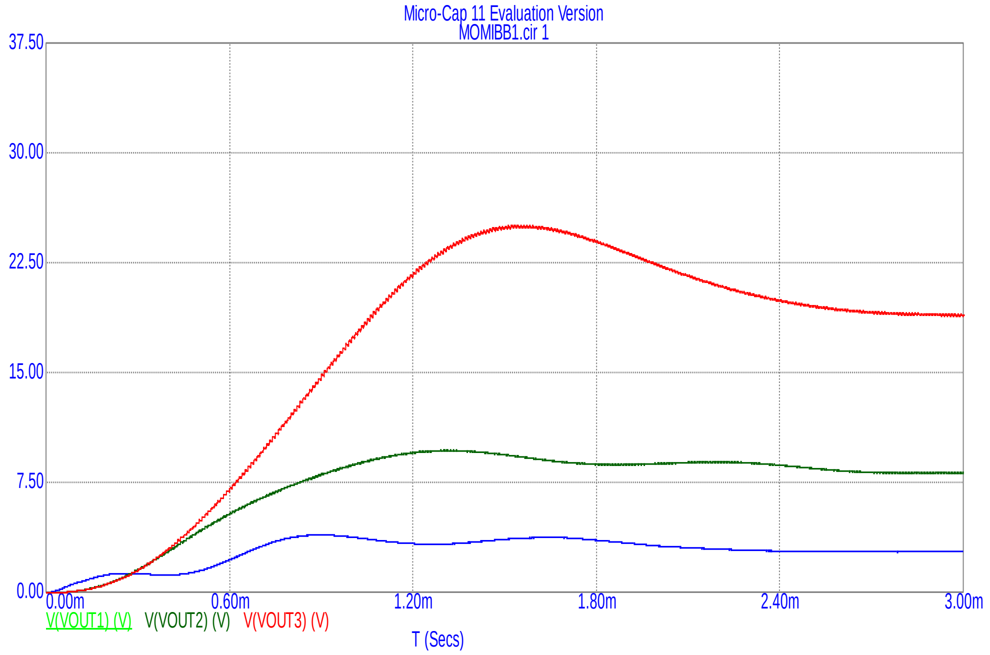

Figure 5.23: Output 1,output 2 and output 3 when increase number of inputs

5.12 Change Number of Outputs

Figure 5.23 shows MIMO BBC when the number of outputs voltages is increased from three to four outputs. The output 1, output 2, output 3 and output 4 are shown in Figure 5.24. The simulation results are showing 3.23v, 7.46v,17.64v and 17.64v respectively. Where the previous result for The output 1, output 2 and output 3 were 2.95v, 8.16v,19.09v respectively,. Similarly, the error in the output voltage can be used to control the duty cycle of the converter through a control circuit.

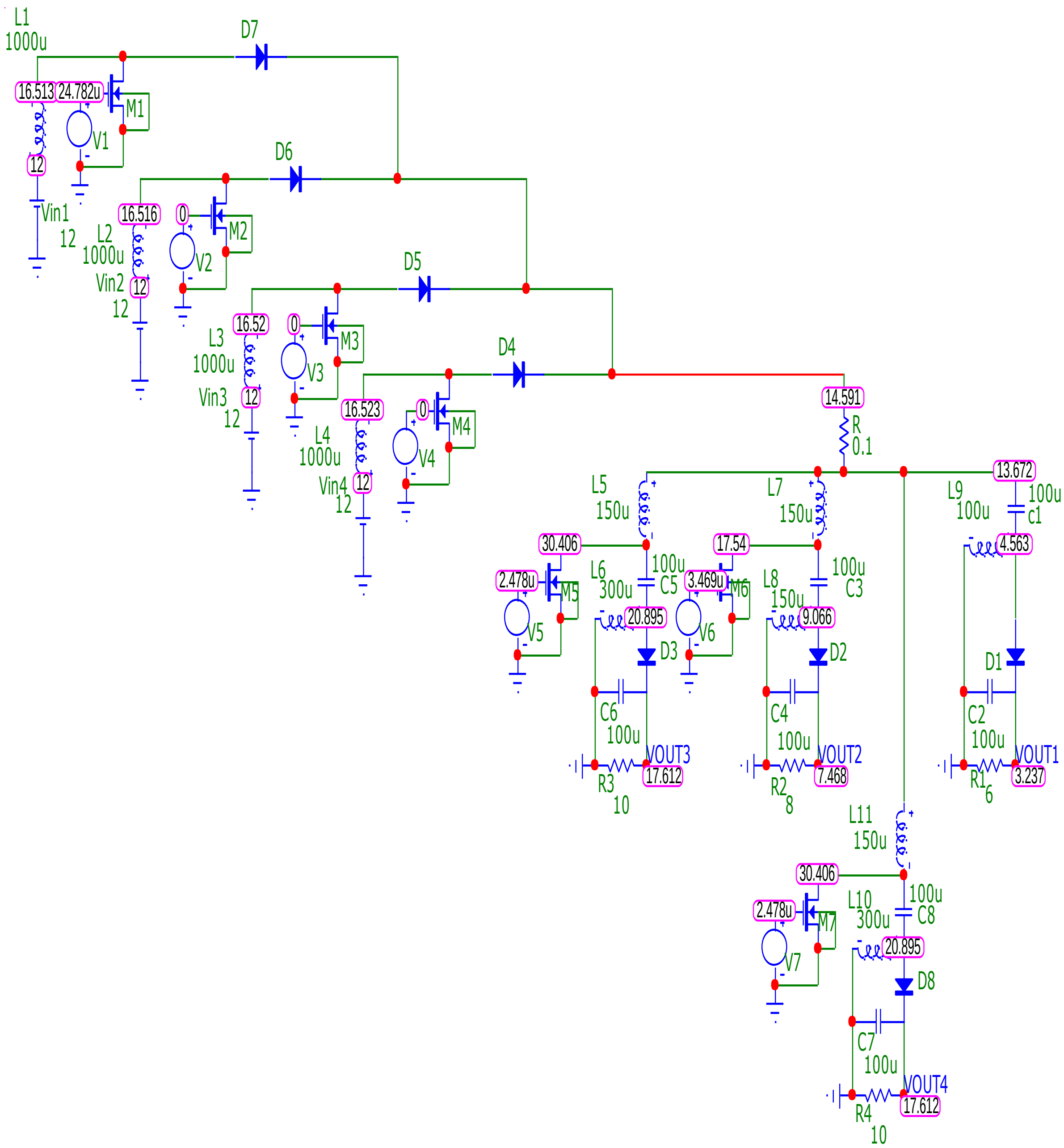

Figure 5 .24: MIMO BBC when increase number of outputs

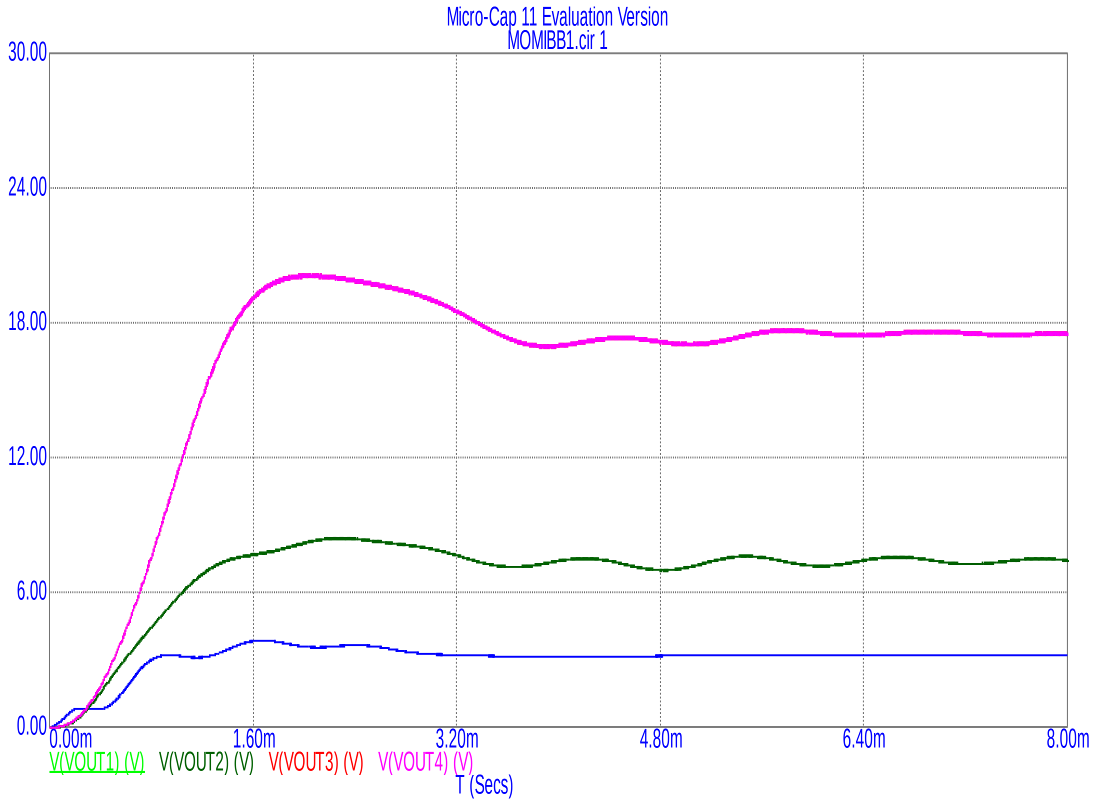

Figure 5 .25: Output 1, output 2 and output 3when increase number of outputs

CHPTER 6

CONCLUSION AND FUTURE PESPECTIVES

6.1 Summary

This thesis contains many topics that give much interest to research in the field of power electronics supply and resources, before conclusions can summarize the next points:

1. Topology: Multi input and Multi output topology is possible to constructed by using more than one method, This will lead to a difference in their characteristics and specifications and hence their diversity.

2. Buck-boost converter: It was the main body in the system, although there are many other methods of another types which result in electronic circuits having other features and characteristics.

3. Control strategy: Control strategy is a critical factor in building a good performance of the system as a whole has a direct impact on the time of opening and closing and thus their strong and direct effects.

4. Number of elements: One of the most important parameters of the power source is the quantity of lost power which is considered a decisive factor when the user takes her decision.

5. Number of inputs: The number of sources of capacity that feed the rest of the system, the greater the number of sources of income this enables the system to continue to work even when a defect in one or more of these elements.

6. Number of outputs: The capacity of the system is a specific factor in the quantity of power output that can be supplied by the system, but it is possible to increase the output capacity, according to the quantity of the power input determined by the number and variety of sources of income.

7. Operation frequency: During the past years, research has been concerned with the frequency of operation of its importance. Many of them are interested in increasing the value of this frequency because increasing it leads to the speed of closing and opening of the transistors used. The advantages of increasing frequency are the possibility of using small electronic components.

8. Isolation: The connection between the input and output of the power electronic is done with an isolation transformer, it provides many advantages and desired by many of the designers.

6.2 Conclusion

The aim of this thesis is to attempt, to construct and simulate the source of an electronic power supply which has multiple ports for both the input and the output, with more attention in topology and have more confidence than others.

An increase in the reliability of the circuit was arranged in the topology so that it was split and divided into the first inductor of the Buck-Boost-Converter to a number of inductor and then connect these inductors to all the sources of input respectively and by increasing these parts leads to more reliability in the whole system.

Increasing the number of inductors resulted in a decrease in the efficiency of the circuit, but this problem was reduced by increasing the used operating frequency and raised to 100 kHz and thus led to the small volume of inductors used and thus to decrease the power losses and thus increase the efficiency of the circuit.

Generated options during the implementation of the circuit by adding the protection diodes which in turn led to a lack of efficiency, but are necessary to increase the reliability of the whole system, but one of the important problems caused by this unified "floating-point", which consists at one terminal of the capacitor C_1.

The floating-point on the terminal of the capacitor C_1 was solved by the construction of a control strategy that enables the terminal of the capacitor C_1 to contact the ground through the source and drain of both switches M5 and M6 during the closing period.

6.3 Future Perspectives

With what has been achieved through previous studies and through study and analysis of this subject during the period of the year found that there is a lot of work requires completion they but not limited to:

- Increase switching frequency and isolated transformer
- Smart power electronic
- Output regulation
- Input regulation

REFERENCES

Banaei, M., Ardi, H., & Farakhor, A. (2014). Analysis and Imlementation of a New Single-Switch Buck-Boost DC-DC Converter. *IET Power Electronics.*

Behjati, H., & Davoudi, A. (2013). A Multiple-Input Multiple -Output DC-DC Converter. *IEEE Transaction on Industry Applications.*

Bukar, A., Said, B., Abubakar B., Musa, K., & Benisheikh, U., (2015). Design of a Non-Ideeal Buck-Boost Converter International. *Journal of Scientific & Engineering Research,Volume 6, Issue 7, July-2015 392 ISSN 2229-5518 IJSER © 2015. http://www.ij=* ser.org.

Baylor, (2012). EE426, Power Electronic DC-DC Converter. Retried from htt://www. baylor.edu

Behjati, H., & Davoudi, A. (2012). A MIMO Topology with Series Outputs: An Interface Diversified Enegy Sources and Diode-Clamped Mulilevel Inverter. *IEEE.*

Choung, S., & Kwasinski, A. (2008). Multiple-Input DC-DC Converter Topologies Comparision. *IEEE.*

Dobbs, B., & Chapman, P. (2003). A Multiple-Input DC-DC Converter Topology. *IEEE Power Electronic Letters.*

Insturment, T. (1999). Understanding Buck Boost Power Stage in Switching Power Supples. http://www.ti.com/lit/an/slva057/slva057.pdf

Jafari, M., Hunter, G., & Zhu, J. (2012). A New Topology of Multi-Input Multi-Output Buck-Boost DC-DC Conveter for Microgrid Application. *IEE International conference on power and energy. Kota Kinabalu Sabah: IEEE.*

Kwasinski, A. Onwchekwa, C. (2011). Analysis of Boundary Control for a Multiple-Input DC-DC Converter Topology. *USA.*

Khaligh, A. (2008). A Multiple-Input Dc-Dc Positive Buck-Boost Cnverter Topology. *IEEE.*

Kumar, L., & Jain, S. (2013). Multiple-Input DC-DC Converter Topology for Hybrid Energy System. *IET Power Electronics.*

Kwasinski, A. (2009). Identification of Feasible Topologies for Multiple-Input DC–DC Converters.

M. Subba Rao, Ch. Sai Babu, S. Satynarayana. (2011). Analysis and Control of Double-Input Integrated Buck-Boost Converter Hybrid Electric. *India.*

Madsen, M. (2015). Very High Frequency Switching-Mode power Supply. *Phd Thesis, Technical University of Denmark.*

Microship. (2017). Buck Design retrieved from, http//satcom.connarelli,files/SMPS Buck Design_0318.9.PDF.,

Rashid, M. (2012). Power Electronic Hand Devices, Circuit, & Applications. *Fellow IET (UK).*

Ray, O., Prasad, A., & Mishra, S. (2012). AMulti-port DC-DC Converter topology with simulataneous Buck and Boost outputs. *International Journal of Research and Engineering.*

Sivaprasad, A., Kumaravel, S., Ashok, S. (2015). Design and Analysis of a Dual Input Buck-Boost Converter for Renewable Energy Application, *International Journal of Scientific & Engineering Research, Volume 6, Issue 5, May-2015 330 ISSN 2229-5518 IJSER.*

Spectrum-Soft. (2012). Micro Cap 11. Spectrum-Soft. Retrieved from,*http://www.spectrum-soft.com/demoform.shum*

Vujanic, R. (2008). Design and Control of a Buck-Boost. https://pdfs.semanticscholar.org.

Xu, L. (2009). Control of Power Converter for Grid Integration of Renewable Energ Converter & Statcom Systems. *Tuscaloosa,Alabama.*

Ye, H., Luo, F., Rashid, M. (2005). Digital Power Electronics and Aplications. ISBN:0-1208-8757-6.