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Study and control of the Z-source inverter

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In the realization of this work

*

DEDICATION

To our ***parents*** and our Family ***IDRICI*** and ***BABANNA***

To our ***Brothers*** and ***Sisters***

To our ***Best friends….***

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LIST OF ABBREVIATIONS AND SYMBOLS

ZSI: z-source inverter

ST: shoot-through state

MBC: maximum boost control

MCBC: maximum constant boost control

CBC: constant boost control

SBC: simple boost control

PWM: pulse width modulation

BZSI: Bidirectional z-source inverter

QZSI: quasi z-source inverter

HP-ZSI: high performance z-source inverter

IZSI: The improved z-source inverter

C1: z-source impedance capacitor

C2: z-source impedance capacitor

L1: z-source impedance inductor

L2: z-source impedance inductor

B: boost factor

d: duty cycle

G : the voltage gain

T: the control cycle

T_{sh}: shoot − through time

T_0: Time interval of the zero vector U0

T_1: time interval of active vector U1

T_2: Time interval of the active vector U2

U1: active vector 1

U2 : active vector 2

m: modulation index

V_{dc}: input voltage of the impedance network

Vc: capacitor voltage of impedance network

Vi: output voltage of impedance network

$\hat{v}_{an}$: the peak value of the output phase voltage

V_n: negative straigh line

V_p: positive straight line

R_L: resistive load

ts: Sampling time

fsw: switching frequency.

I_{oc}: Short-circuit current.

K_I: short circuit current temperature coefficient

V_{mp}: voltage at maximum power

I_{mp}: current at maximum power

I_{RS}: reverse saturation current at a reference condition

I_{sh}: shunt curent

I_d: diode curent

GENERAL INTRODUCTION

One of the most promising power electronics converter topologies is the Z-source inverter (ZSI). The ZSI is an emerging topology for power electronics dc–ac converters with interesting properties such as buck-boost characteristics and single stage conversion. A two port network, composed of two capacitors and two inductors connected in an X shape, is employed to provide an impedance source (Z-source) network, coupling the inverter main circuit to the dc input source. The ZSI advantageously uses the shoot-through (ST) state to boost the input voltage, which improves the inverter reliability and enlarges its application fields. In comparison with other power electronics converters, it provides an attractive single stage DC–AC conversion with buck-boost capability with reduced cost, reduced volume, and higher efficiency due to a lower component number. For emerging power-generation technologies, such as fuel cells, photovoltaic (PV) arrays, and wind turbines, and new power electronic applications such as electric and hybrid vehicles, the ZSI is a very promising and competitive topology [1]–[4]. The Z-source concept can be applied to all DC–AC, AC–DC, AC–AC, and DC–DC power conversion. In addition, it can be used as voltage or current fed ZSI for two-level or multilevel configuration.

The objective of this dissertation is to study the different control strategies used for the z-source inverter. Especially the modified pulse width modulation. This dissertation also presents a comparative study between the mentioned strategies to determine which one provides the best efficiency.

To present this dissertation work, the manuscript is organized as follow:

This introduction presents the problem statement and the objective of this dissertation. Chapter 1 is comprised of a literature review about the different topologies of the z-source inverter, also present advantages and disadvantages of ZSI, and Comparison between CSI, VSI and ZSI.

Chapter 2 presents a control strategy: simple boost control SBC, maximum boost control MBC, maximum constant boost control. Chapter 3 presents a comparative study between the different existing control strategies: SBC, MBC, MCBC. and We showed results of simulation control strategies.

CHAPTER 1
LITERATURE REVIEW OF Z-SOURCE

1.1. INTRODUCTION

Z-source inverter (ZSI) is a type of power electronic converter that has gained significant attention in recent years due to its unique features such as voltage boosting, inverting, and buck-boosting capabilities. The ZSI operates by using a unique impedance network called the Z-source network, which enables the inverter to process power with greater efficiency and flexibility compared to traditional inverters [1].

The Z-source network consists of a passive impedance circuit that is connected in between the DC source and inverter circuit. The impedance network can be designed using various components such as inductors, capacitors. The ZSI provides several advantages such as reduced cost, improved efficiency, and increased flexibility in terms of voltage and power flow control [4].

Z-source inverters find applications in a wide range of fields, including renewable energy systems, electric vehicles, and motor drives. They are also being investigated for their potential use in grid-tied systems to improve the reliability and stability of the power grid [5].

1.2. Principle of operation and analysis of the Z-source inverter

The general operation of a Z-source inverter ZSI inverter can be illustrated by considering the AC part of the circuit as an 'equivalent' DC load (or source) [6].

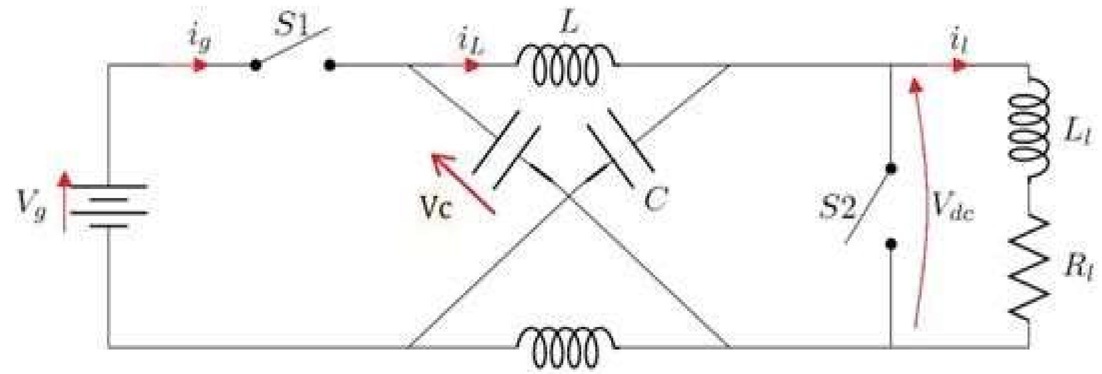


Figure (1-1): Simplified diagram of a ZSC inverter

To simplify the study, we content ourselves with an equivalent schema (Figure1-1), we have two states in the shoot-through state the ZS circuit is short-circuited. In the active state the ZS impedance network sees the load through the inverter. The following assumptions are made:

L1 = L2 = L and C1 = C2 = C, so we have a symmetrical circuit,

where Vc1 = Vc2 = Vc and Il1 =Il2 = Il.

With Vg, Vc, Vl and Vdc: represent respectively the voltages of the DC source, the capacitor, the inductor and the output of the ZSC. Il, Ig, Il, Ic: are respectively the load and source currents and the currents flowing through the inductor and the capacitor. There are four 'states' to be presented, they depend on the configurations of switches S1 and S2 [7].

1.2.1. State 1: Shoot- Through

When switch S1 is open and S2 is closed, the impedance network ZS is short circuited. In this case the voltage of the load is zero and there is no transfer of energy. The duration of the shoot-through state is equal to T0, and the switching period is equal to T [8].

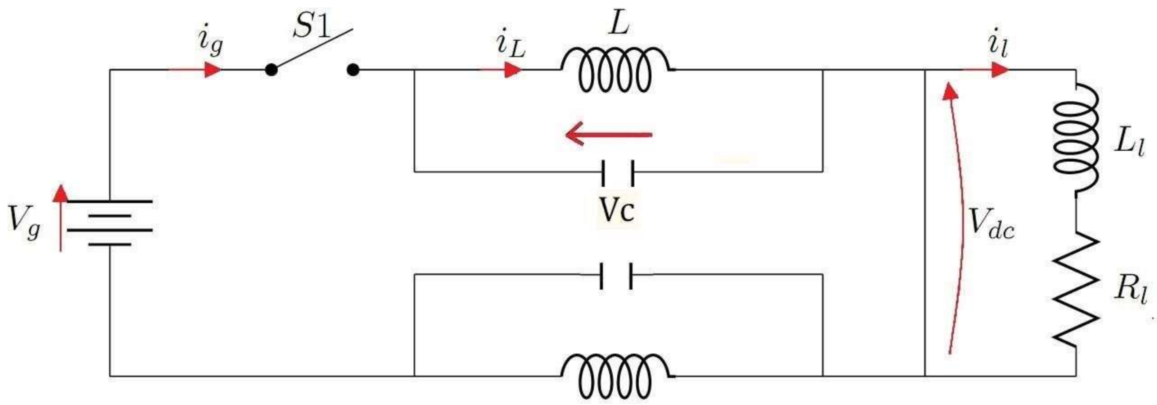


Figure (1-2): State Shoot- Through

We note that Vc = V l, it follows.[8]:

$$\begin{cases} \frac{d_{vc}}{dt} = - \frac{iL}{c} \\ \frac{d_{il}}{dt} = -\frac{v_c}{l} \\ v_{dc} = 0 \\ i_g = 0 \end{cases} \quad (1)$$

1.2.2. State 2 Active State

If the converter is in the active state, the switch S2 is open and S1 is closed as shown in Figure (1-3). The duration of this state is (T − T0). In this state, there is a transfer of energy [8].

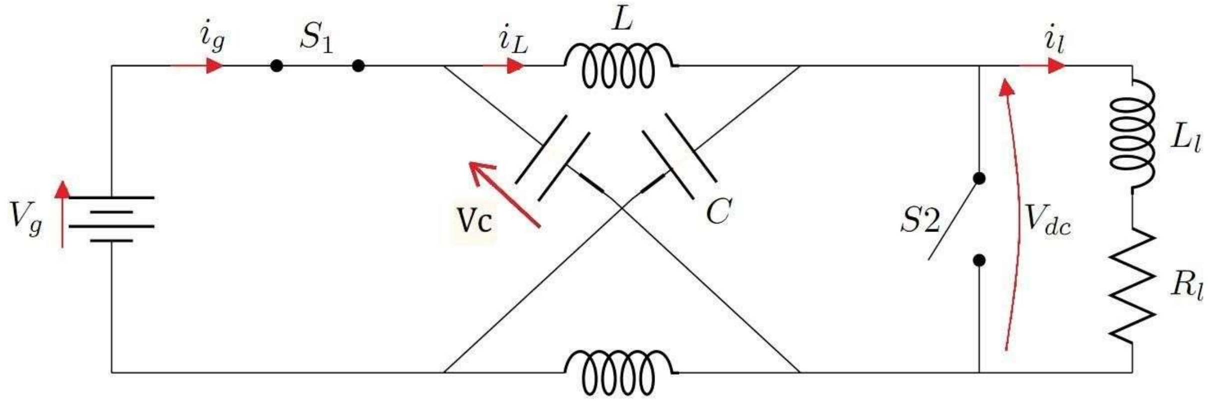


Figure (1-3): Active State

$v_l = v_g - v_c \; et \; i_g = i_l + i_c = i_l + c\frac{d_{vc}}{dt}$, it follows.

$$\begin{cases} \frac{d_{vc}}{dt} = -\frac{i_g - i_l}{c} \\ \frac{di_l}{dt} = -\frac{v_g - v_c}{l} \\ v_{dc} = v_c - v_l = 2v_c - v_g \\ i_g = i_l + i_c \end{cases} \quad (2)$$

1.2.3. State 3: Zero State

when S1 = 0 and S2 = 0, we have: *Il* = −*Ic* = *Il*

$$\begin{cases} \frac{d_{vc}}{dt} = -\frac{iL}{c} \\ \frac{d_{il}}{dt} = -\frac{v_c - v_{dc}}{l} \\ v_{dc} = v_c - v_l \\ i_g = 0 \end{cases} \quad (3)$$

1.3. Boost factor B

In the steady state, we know that the average value of the voltage during a switching period at the inductor is zero, therefore [8] :

$$V_l = \frac{1}{T}\left[\int_0^{T0} v_c dt + \int_{T0}^{T}(v_g - v_c)dt\right] = 0 \quad (4)$$

$$V_c = \frac{1-\frac{T_0}{T}}{1-2\frac{T_0}{T}}V_g \quad (5)$$

we set $d = \frac{T_0}{T}$. d is the duty cycle, we get:

$$V_c = \frac{1-D}{1-2D} V_g \quad (6)$$

On the other hand, the maximum voltage of the DC bus in a state of equilibrium is written:

$$v_{dcn} = 2v_c - v_g \quad (7)$$

We therefore obtain the relationship between the input voltage and the maximum DC bus voltage:

$$v_{dcn} = \frac{1}{1-2D} v_g = Bv_g \quad (8)$$

Where B is the boost factor.

$$B = \frac{1}{1-2D} \quad (9)$$

1.4. Advantages and disadvantages of ZSI

The ZSI not only has a Buck-boost function, but also lacks the time to suppression traditionally present in an ordinary inverter. The advantages that ZSI versus traditional VSI or CSI are not limited but extend to following elements:

The ZSI (Zero Voltage Switching Inverter) is a versatile DC input source that extends beyond batteries to include various other sources such as voltage or current sources, as well as loads like diode rectifiers, transistor converters, inductors, capacitors, and more. This flexibility allows the ZSI to be employed in a wide range of applications, including variable output voltage sources like fuel cells and photovoltaic networks. By utilizing the ZSI, the AC voltage can be adjusted to any desired value within the range from zero to high magnitudes. Unlike VSI (Voltage Source Inverter) or CSI (Current Source Inverter), the ZSI operates as a Buck-Boost inverter, which offers unique advantages. Additionally, the ZSI can be controlled using various PWM (Pulse Width Modulation) schemes, providing enhanced flexibility. This makes the ZSI applicable across all power conversion ranges, further highlighting its versatility. As disadvantage, the identified RHP zero in Z-source impedance network can’t be eliminated by adjusting the Z-source parameters. Compensation methods need further investigations.

1.5.Comparison between CSI, VSI and ZSI

Table (1-1): Comparison between CSI, VSI and ZSI [10].

source inverter	Current source inverter	Z-Source Inverter
The CSI acts as a constant current source or a rigid current since a large inductor is used in series with the voltage source	The VSI acts as a constant voltage source or a rigid voltage inverter since a large capacitor is used in parallel with the voltage source.	The ZSI acts as a constant source of high impedance voltage. As a capacitor and inductor is used in the CC link.
A CSI is able to withstand short circuits on two of its output terminals. Hence momentary short-circuit in load .	A VSI is a more dangerous situation because the parallel capacitor feeds more power to the fault.	In ZSI misfires of switches is sometimes also acceptable.
Cannot be used in both buck or boost operation of inverter at the same time.	Cannot be used in both buck or boost operation of inverter at the same time.	Can be used in both buck and boost operation of inverter at the same time.
The main circuits cannot be interchangeable.	The main circuit cannot be interchangeable here too.	Here, the main circuits are interchangeable.
It is affected by EMI noise.	It is affected by EMI noise.	It is less affected by EMII noise.
It has a considerable amount of harmonic distortion.	It has a considerable amount of harmonic distortion.	Harmonics Distortion in the bass.
The power loss should be high in filter reason	Power loss is high	Power loss should be low
Observed that power loss decreases efficiency here.	The high-power loss decreases efficiency here.	Higher efficiency due to less power loss

1.6. Topologies

1.6.1 Bidirectional Power Flow

The basic version of ZSI topology can be changed into a bidirectional ZSI (BZSI). As shown in Figure (1-4), the input diode *D* is replaced by a bidirectional switch S_7. The BZSI is able to exchange energy between ac and dc energy storages in both directions. Also, the BZSI is able to completely avoid the undesirable operation modes when the ZSI is operating under a small inductance or a low load-power factor [11].[13].

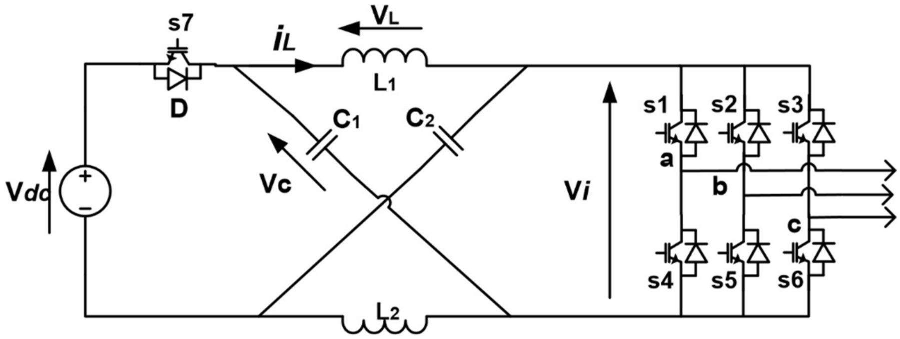


Figure (1-4): Bidirectional ZSI

1.6.2 High-performance ZSI

The high-performance ZSI (HP-ZSI) shown in Figure (1-5) can operate at a wide load range with a small Z-network inductor. It can eliminate the possibility of the dc link voltage drops. It simplifies the Z-network inductor design and system control. The HP-ZSI is derived from the basic ZSI topology by adding an additional capacitor, *C*, and a bidirectional switch, S_7 [12], [9].

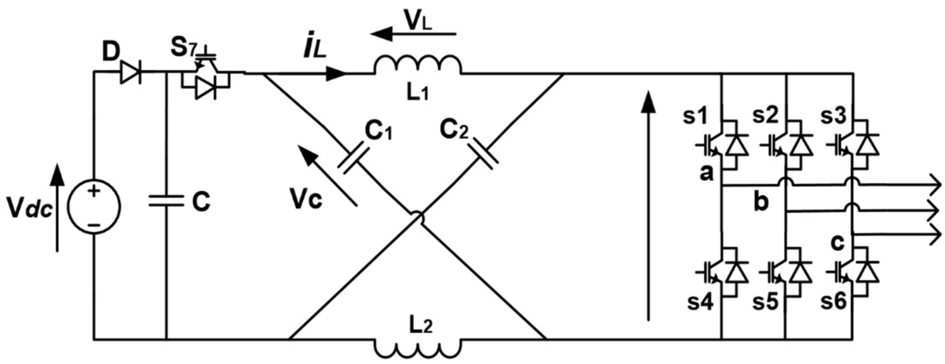


Figure (1-5): The high-performance ZSI

1.6.3. Soft-switching

Quasi-resonant soft-switching Z-source inverter (QRSSZSI) is formed by adding a quasi-resonant network with only one auxiliary switch to achieve the soft switching. As shown in Figure (1-6), all switches in the inverter bridge are turned on and off under a zero-voltage switching condition. The QRSSZSI had almost a 10% overall efficiency increase compared with the hard switching one [14].

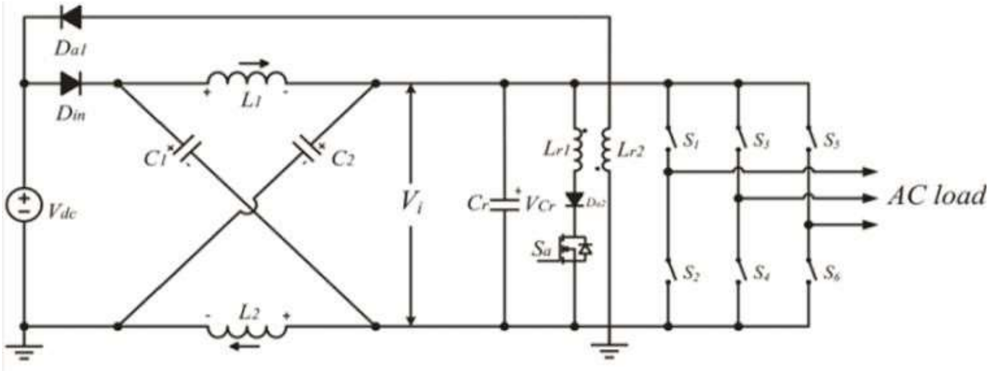


Figure (1-6): The soft-switching ZSI

1.6.4. The improved ZSI

A huge inrush current accrues at ZSI start-up. The initial voltage across the Z-source capacitors is zero, so a huge inrush current charge the capacitors immediately to half the input voltage. Then, the resonance of Z-source capacitors and inductors starts, which results in large voltage and current surge, which might destroy the devices. Because of the inherent current path at startup in the basic ZSI topology, it cannot achieve the soft-start capability to suppress resonant current at startup.

The improved ZSI (IZSI), as shown in Figure (1-7), is derived from the basic ZSI topology by exchanging the positions of the inverter bridge and the input diode and inversing their connection directions. The elements used are the same as the basic ZSI topology. Although the IZSI produces the same voltage boost, the capacitor voltage stress can be reduced to a significant extent. In addition, it has an inherent inrush-current limitation ability because there is no current path at start-up [15], [16]. In [17], the IZSI has been combined with the HP-ZSI topology to produce the high-performance IZSI (HP-IZSI). The HP-IZSI has two merits: one is the low voltage stresses of the Z-source network capacitors, and the other is inherent limitation to inrush current and voltage at startup.

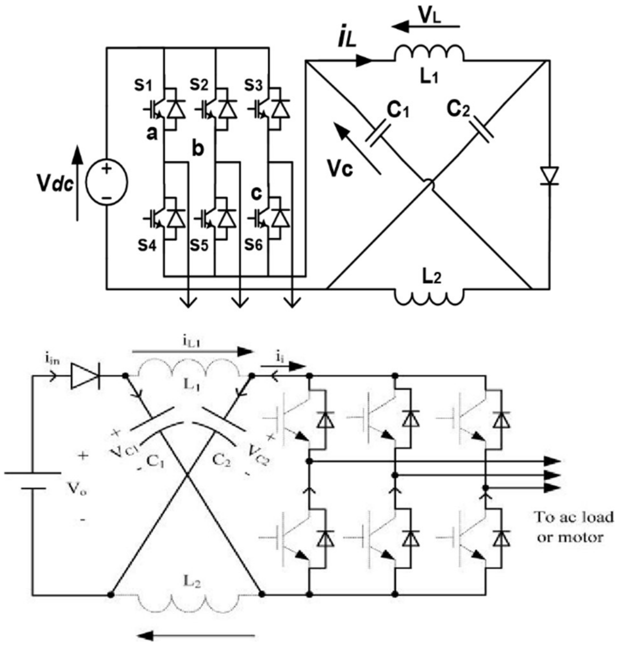


Figure (1-7): The improved ZSI

1.6.5. Neutral point ZSI

The application of the ZSI four-wire systems has been solved by many proposed solutions. In [18], a four-wire ZSI (FWZSI) was proposed based on the HP-ZSI topology. An additional bidirectional switch is add in the negative current path and splitting the input dc capacitor to obtain a neutral point. Another solution has been proposed in [19]: adding a fourth inverter leg to obtain a virtual dc-link at a zero point, which is called four-leg ZSI (FLZSI)in figure (1-8). (1-9). Another ZSI for a four-wire system, is the dual ZSI (DuZSI). It consists of two three-phase transistor modules, which work on a common load and with a single dc source. The DuZSI has improved output voltage quality and reduced current stress because of the current distribution between the two inverter bridges.

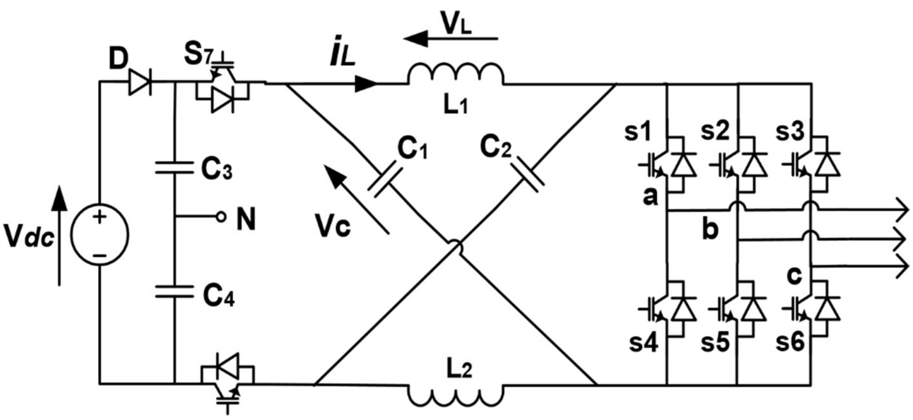


Figure (1-8): four-wire ZSI

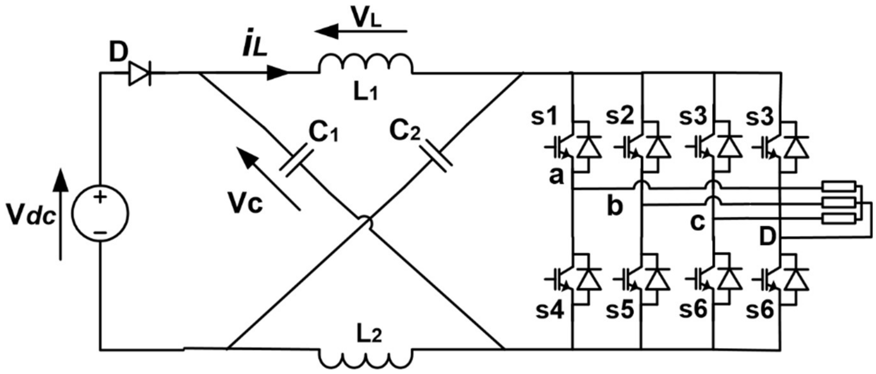


Figure (1-9): four-leg ZSI (FLZSI)

1.7. Conclusion

In this chapter, we were able to theoretically analyse the operation of the Z-source inverter and establish the output equations of the converter. The Z-source inverter uses a unique impedance network to couple the main circuit of the inverter to the DC power source, and thus provide boosted AC voltage. In this chapter we were able to see the particularity of this type of converter which is characterized by the insertion of a Shoot through, which allows us to obtain at the end amplified voltages. In this chapter the various Z-source topologies proposed in the literature, and the different control strategies used for Z-source inverters are presented in the next chapter.

CHAPTER 2
Z-source Control Strategies

2.1. INTRODUCTION

In this chapter we explaining the most important part about ZSI the three existing control strategies The simple boost control, the Maximum Boost Control and the Maximum constant boost control, with mathematical equation and do some theoretical comparison between them in terms of finding the best one to control the ZSI perfectly to provide the best efficiency.

2.2. Simple Boost Control

The simple boost method is used to control the duty cycle of Shoot-Through, where we use two horizontal lines (VP and VN), where Vp is equals to or greater than Vref, and VN is less than or equal to -Vref. If the triangular carrier is greater than Vp or less than Vn, ZSI is in the shoot-through state, ZSI maintains the active states of a conventional inverter.

In this method the maximum value of the Shoot-Through duty cycle Dmax decreases if the modulation rate M increases, the maximum value of D is given by:

Dmax = 1 - M (10)

The formulas relating the modulation rate M and the overvoltage factor B discussed in [20] are:

$$B_{max} = \frac{1}{1-2D_{max}} = \frac{1}{1-2(1-M)} \tag{11}$$

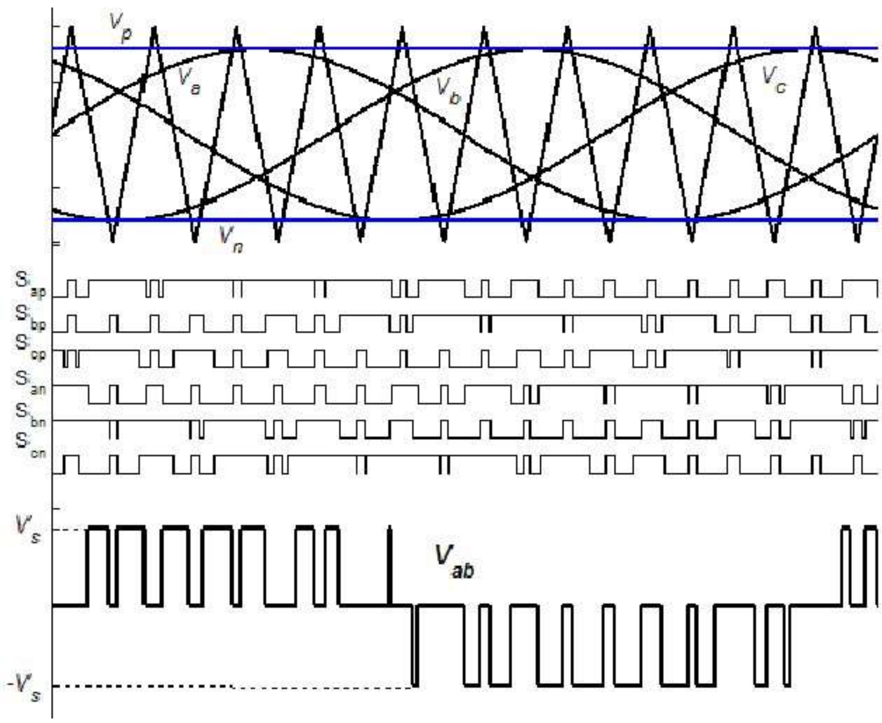


Figure (2-1): The simple boost command

$$M = \frac{B+1}{2B} \tag{12}$$

We will finally have the gain:

$$G = M \times B = \frac{V_{ac}}{V_g/2} = \frac{B+1}{2} \tag{13}$$

We obtain the max gain as a function of M:

$$G_{max} = \frac{M}{2M-1} \tag{14}$$

2.3. Maximum Boost Control

This approach converts all zero states of a traditional inverter to a straight-through state (almost similar to a traditional MLI) while keeping the active state The method compares the maximum and minimum returns with the carrier Triangle if maximum is below support or minimum is above support carrier, so ZSI is a "straight-through" regime in which the cycle ratio is Straight D sequence repeats every $\frac{3}{\pi}$ Assuming the switching frequency is much greater than the frequency modulation, the direct ratio within one switching cycle in the interval $\left[\frac{3}{\pi}, \frac{6}{\pi}\right]$.

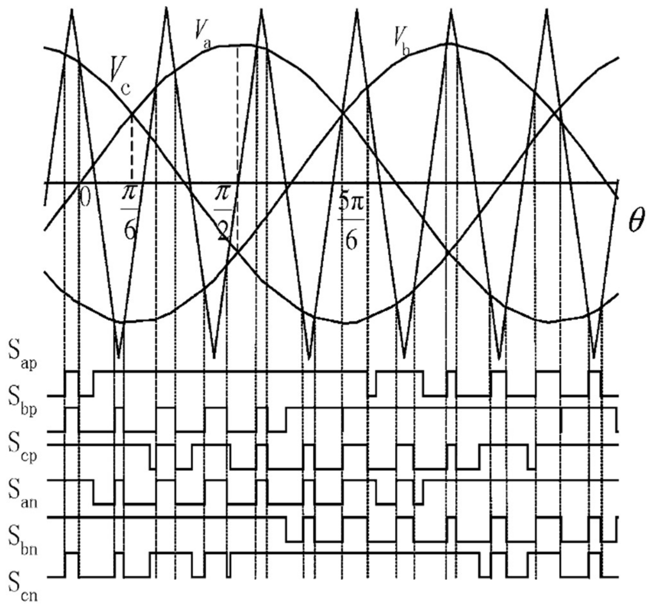


Figure (2-2): Waveforms of maximum boost control.

The duty cycle of the shoot-through average can be calculated as follow:

$$\frac{\bar{T}_{sh}(\theta)}{T_s} = \int_{\frac{\pi}{6}}^{\frac{\pi}{2}} \frac{2-(m\sin\theta - m\sin\left(\theta - \frac{2\pi}{3}\right))}{2} d\theta = \frac{2\pi - 3\sqrt{3}m}{2\pi} \tag{15}$$

$$B = \frac{1}{1-(2\bar{T}_{sh}/T_s)} = \frac{\pi}{3\sqrt{3}-\pi} \quad (16)$$

and for a given boost factor B, the modulation index for the MBC strategy can be calculated as:

$$m = \frac{\pi(B+1)}{3\sqrt{3}B} \quad (17)$$

Therefore, the voltage gain can be defined as:

$$G = m.B = \frac{\pi(B+1)}{3\sqrt{3}} \quad (18)$$

2.4. Maximum constant boost control method

Figure. 12 shows the sketch map of the maximum constant boost control method, which achieves the maximum voltage gain while always keeping the shoot-through duty ratio constant. There are five modulation curves in this control method: three reference signals, Va, Vb and Vc, and two shoot-through envelope signals, Vp and Vn. When the carrier triangle wave is greater than the upper shoot-through envelope, Vp, or lower than bottom shoot-through envelope Vn, the inverter is turned to a shoot-through state. In between, the inverter switches in the same way as in the traditional carrier based PWM control [21].

Because the boost factor is determined by the shoot-through duty cycle, the shoot-through duty cycle must be kept the same in order to maintain a constant boost. The basic point is to get the maximum B while keeping it constant all the time. The upper and lower envelope curves are periodical and are three times the output frequency. There are two half-periods for both curves in a cycle. For the first half-period, $(0, \pi/3)$ in Figure. 15, the upper and lower envelops curves can be expressed by (16) and (17), respectively

$$\grave{V}_a(t) = m\sin(\omega t) + \frac{m}{6}\sin(3\omega t) \quad (19)$$

This signal has a maximum amplitude of $\frac{\sqrt{3}}{2}m$, which allows us to deduce that the two straight lines have the following expressions:

$$\begin{cases} V_p = \frac{\sqrt{3}}{2}m \\ V_n = -\frac{\sqrt{3}}{2}m \end{cases} \quad (20)$$

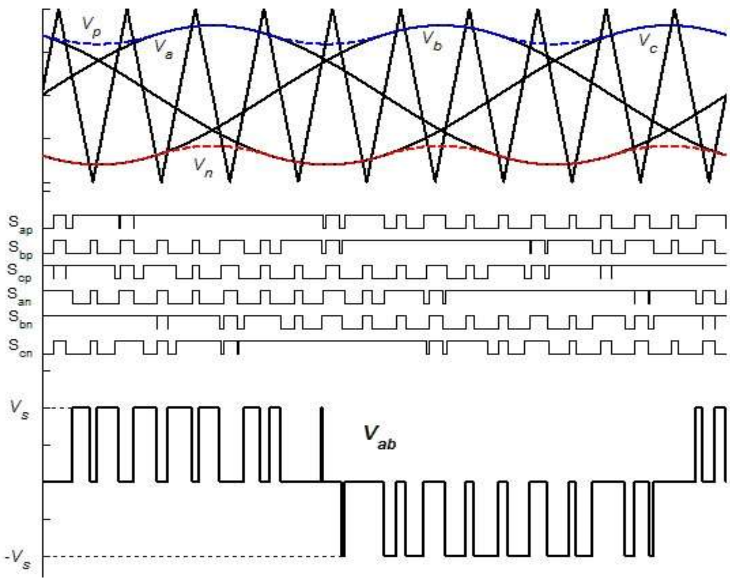


Figure (2-3): Maximum constant boost control method

The calculation of d can be carried out using the same procedure used for the SBC strategy, and it is calculated as follow:

$$d = 1 - \frac{\sqrt{3}}{2}m \tag{21}$$

The replacement of the last expression of the duty cycle d in relations and gives us the expressions of the amplification factor B and the total gain G of the inverter as a function of the modulation index m as follow:

$$B = \frac{1}{\sqrt{3}m-1} \tag{22}$$

$$G = \frac{m}{\sqrt{3}m-1} \tag{23}$$

Therefore, the voltage gain as a function of the boost factor can be defined as:

$$G = \frac{1+B}{\sqrt{3}} \tag{24}$$

2.5. Theoretical comparison

After the study of each strategy in the previous section, in the next section a theoretical study is carried out. Table (2-1) summarize the different analytic expression for each strategy. Figures (2-4) and Figure (2-5) present the characteristics G (B) and the characteristics G (M) for the different control strategies.

Table (2.1): Summary of different PWM control methods expressions

	SBC	MBC	MCBC
d	$1-m$	$\frac{2\pi-3\sqrt{3}m}{2\pi}$	$\frac{2-\sqrt{3}m}{2}$
B	$\frac{1}{2m-1}$	$\frac{\pi}{3\sqrt{3}M-\pi}$	$\frac{1}{\sqrt{3}m-1}$
G	$\frac{m}{2m-1}$	$\frac{\pi m}{3\sqrt{3}m-\pi}$	$\frac{m}{\sqrt{3}m-1}$
G(B)	$\frac{B+1}{2}$	$\frac{\pi(B+1)}{3\sqrt{3}}$	$\frac{B+1}{\sqrt{3}}$

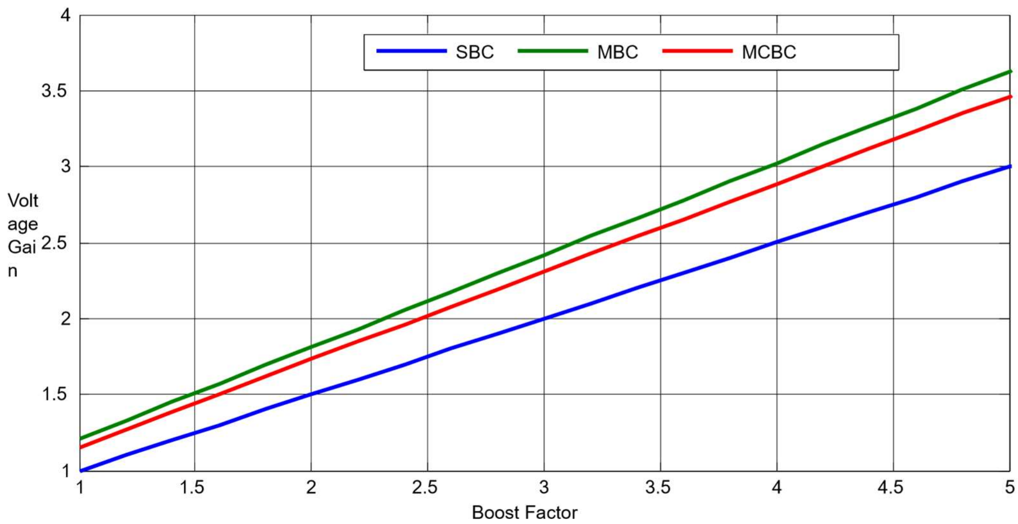


Figure (2-4): characteristics of different strategies (a) The G (B)

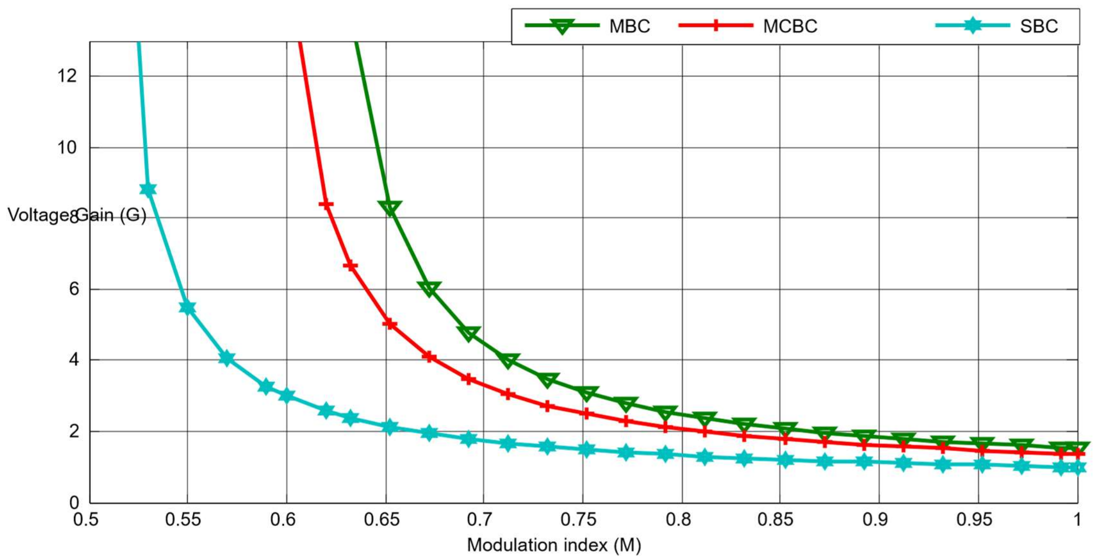


Figure (2-5): Characteristics of different strategies (b) G (M)

As listed in the table (2-1) and showed in the figures (2-4) and (2-5), the SBC method requires a small modulation index to produce high voltage gain. However, for the MCBC, the voltage at the switch terminals that are blocked during the active state is slightly higher than that of the MBC strategy and lower than that of the SBC strategy.

2.5. CONCLUSION

In this chapter, we explained the three control strategies with mathematical equation and do some theoretical comparison between the SBC, MBC, MCBC in terms the boost factor and voltage gain, as results we found that MBC has the highest boost factor and MCBC is more stable than MBC and SBC.

CHAPTER 3

COMPARATIVE STUDY OF EXISTING CONTROL STRATEGIES

3.1. INTRODUCTION

The objective of this chapter is to evaluate the performance of different control strategies mentioned in the previous chapter, in terms of output voltage quality, power efficiency, and dynamic response. MATLAB/Simulink is used, to evaluate and compare between the three control strategies. This study aims to contribute to the understanding and advancement of control strategies for Z-source inverters.

3.2. Simulation results

To evaluate the performance of the control strategy, simulation using

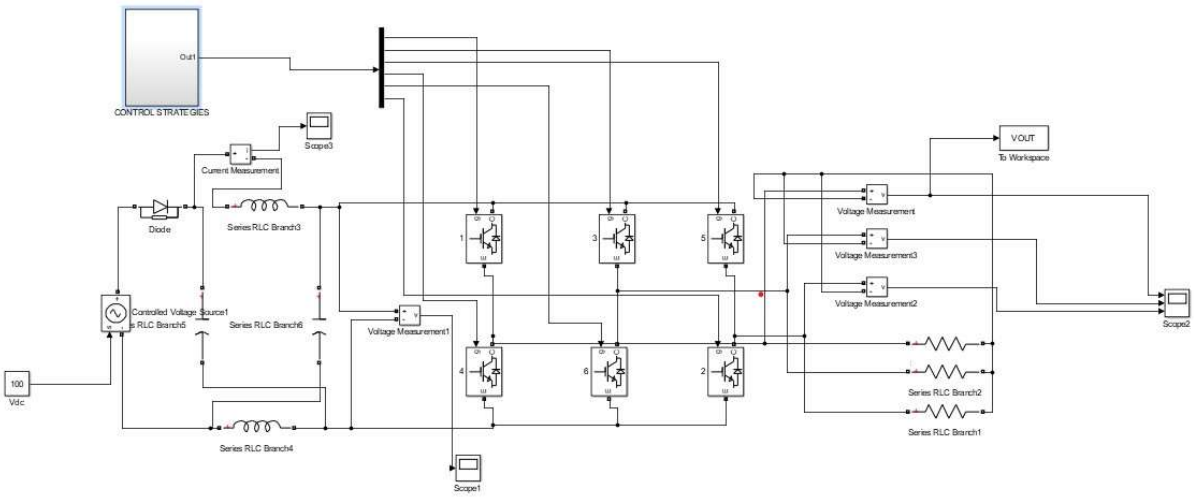


Figure (3-1): Bloc diagram ZSI

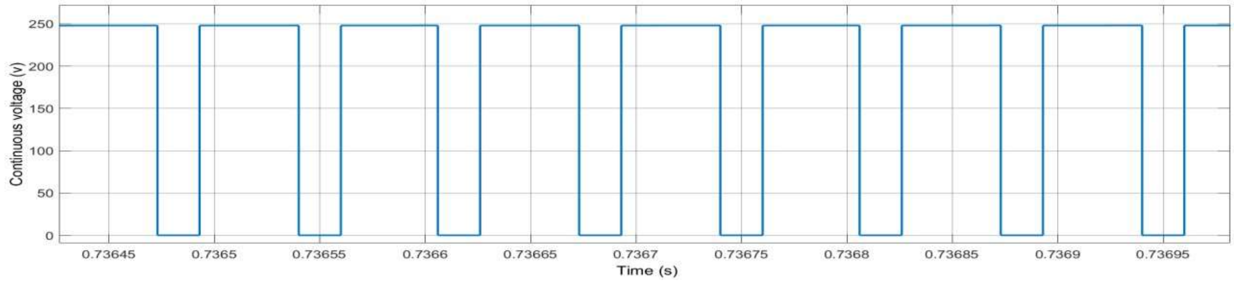
MATLAB/SIMULINK software carried out. As shown in figure (3-1), the system consists of a Z-source inverter linked with a dc source, feeding a three-phase resistive. The main parameters of the described system are listed in table (3-1). This simulation aims to compare between different control strategies mentioned in the previous chapter. The obtained simulation results are listed in table (3-4). The simulation results in continuous time mode for the Continuous voltage (v), Inductance current (A), and Output voltage (v), are plotted from figure (3-2), figure (3-3) and figure (3-4) respectively, and voltage output FFT analysis are shown in figure parts (d)

Table (3-1): Experimental parameters

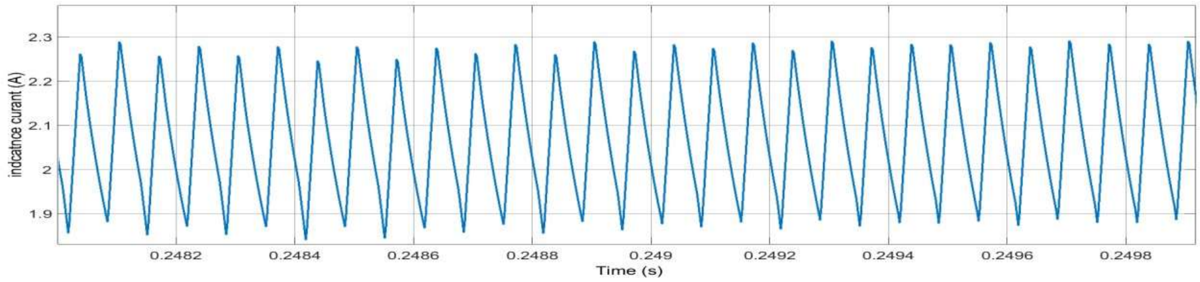
V_{dc}	M	C	f_{sw}	f_s	L_f	R_L
100V	0.8	4.7e3 F	7500KHz	5e7khz	10e-3 h	50 Ω

3.2.1. Simple boost control

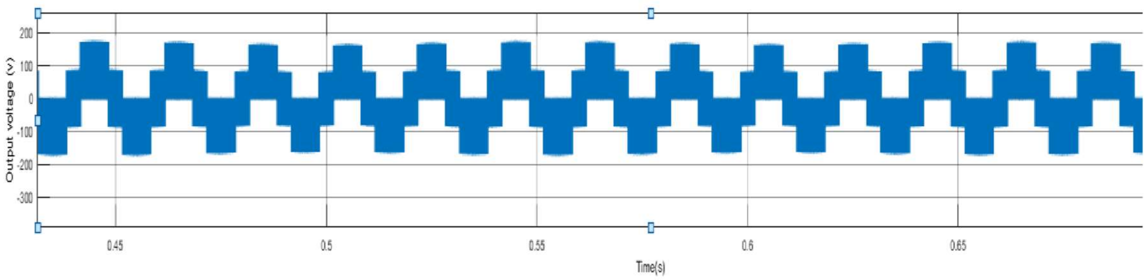
With modulation index (M = 0.7)



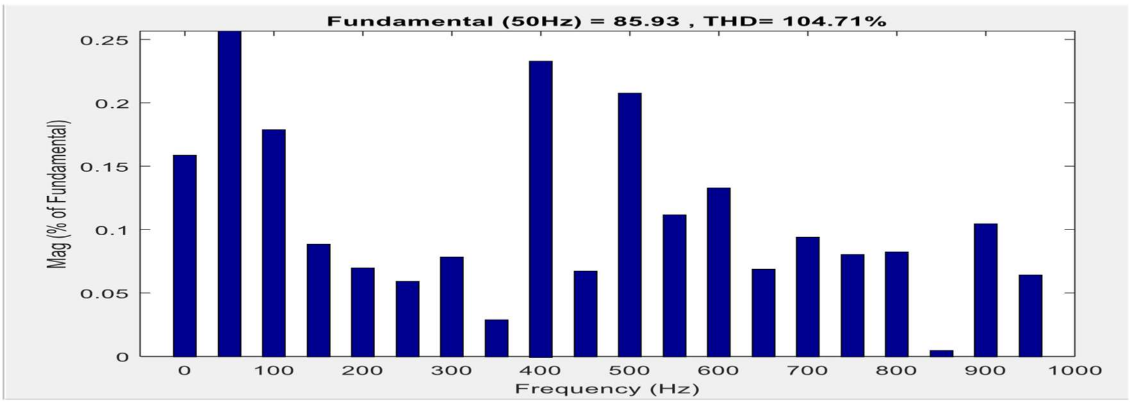
(a)



(b)



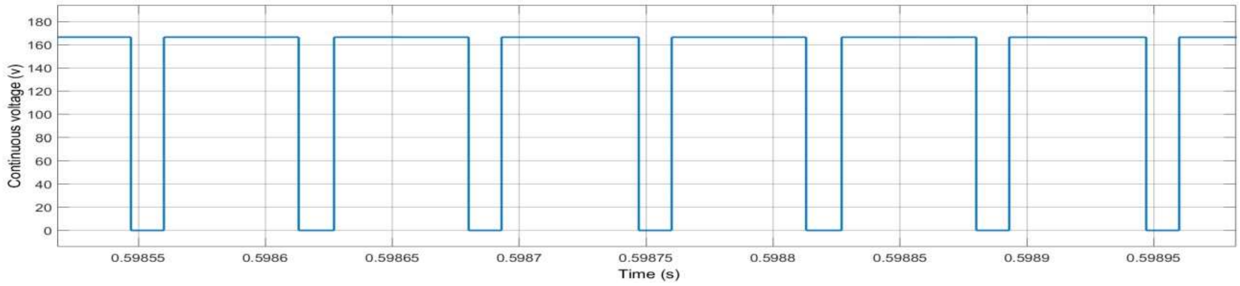
(c)



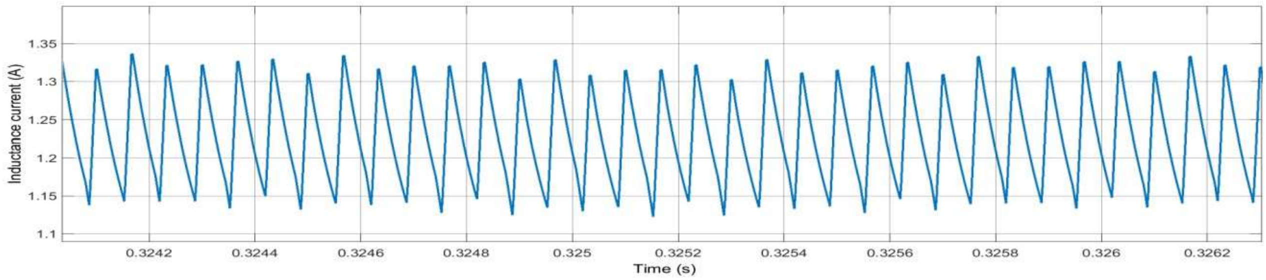
(d)

Figure (3-2): Simulation results SBC (a) Vdc-Vcz & Vg Voltages ;(b ;c zoom) Inductance current ;(d) Van & V1cf voltages; (e) THD (m = 0.7)

With modulation index (M = 0.8)



(a)



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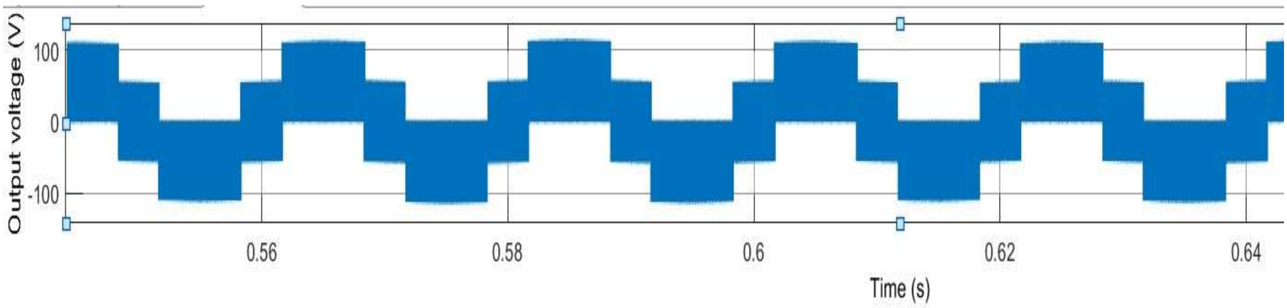

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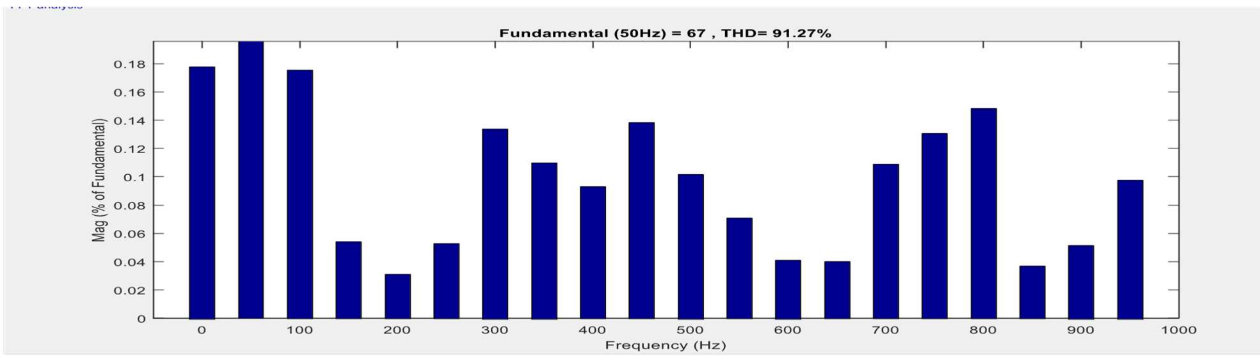
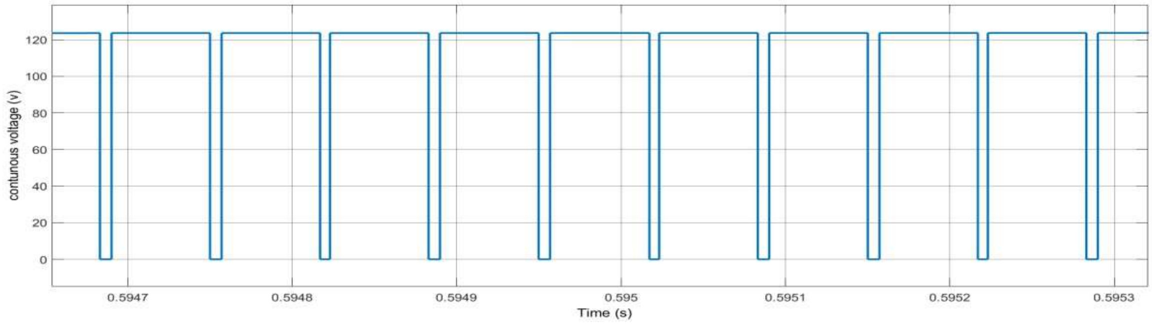


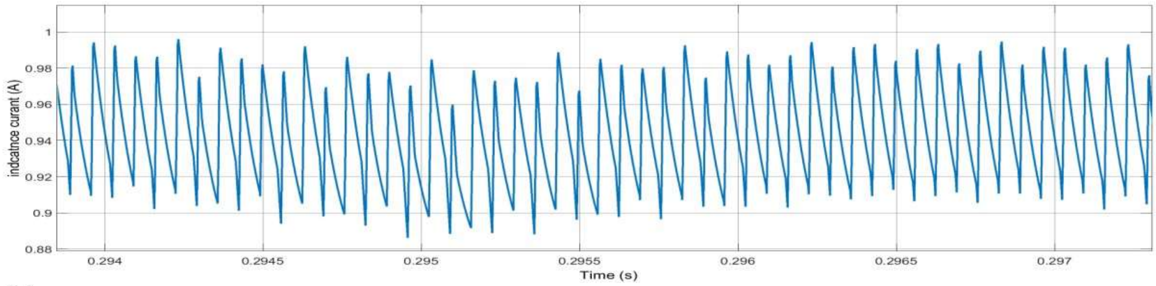
(d)

Figure (3-3): Simulation results SBC (a) Vdc-Vcz & Vg Voltages ;(b ;c zoom) Inductance current ;(d) Van & V1cf voltages; (e) THD (m = 0.8)

With modulation index (M = 0.9)



(a)



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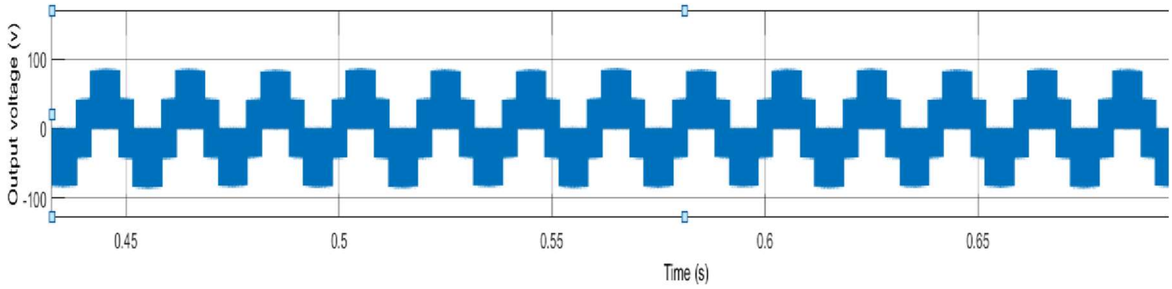

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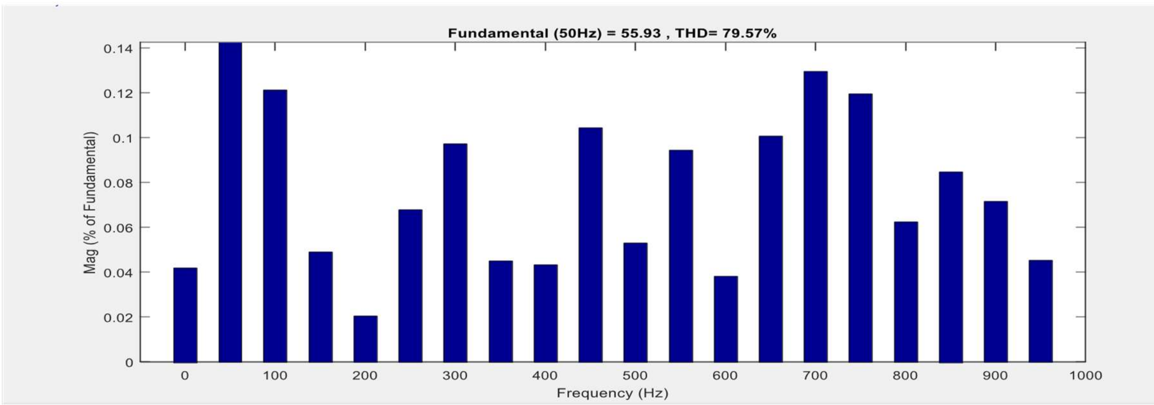
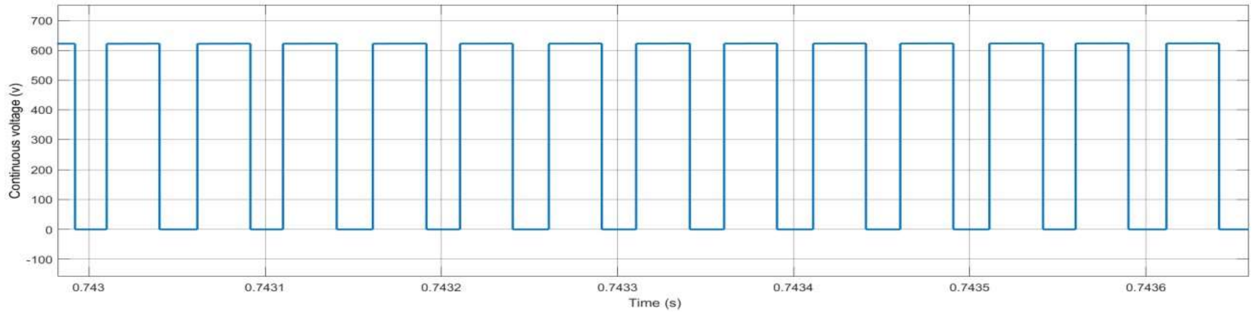


(d)

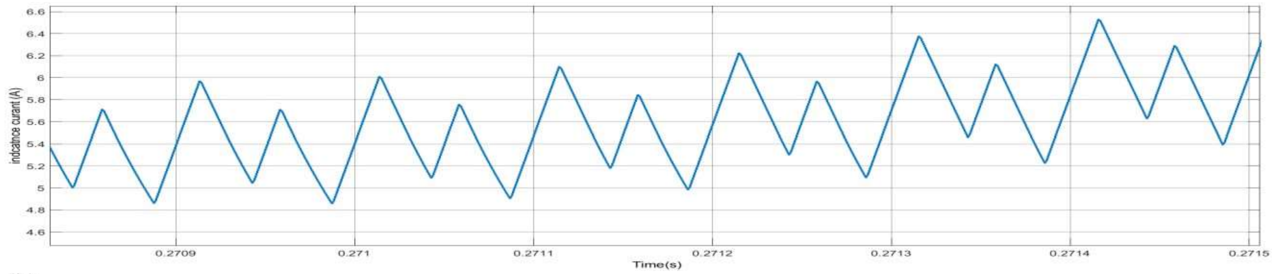
Figure (3-4): Simulation results SBC (a) Vdc Voltages; (b) Inductance current ;(c) Van & V1cf voltages; (d) THD (m= 0.9)

3.2.2. Maximum boost control

With modulation index (M = 0.7)



(a)



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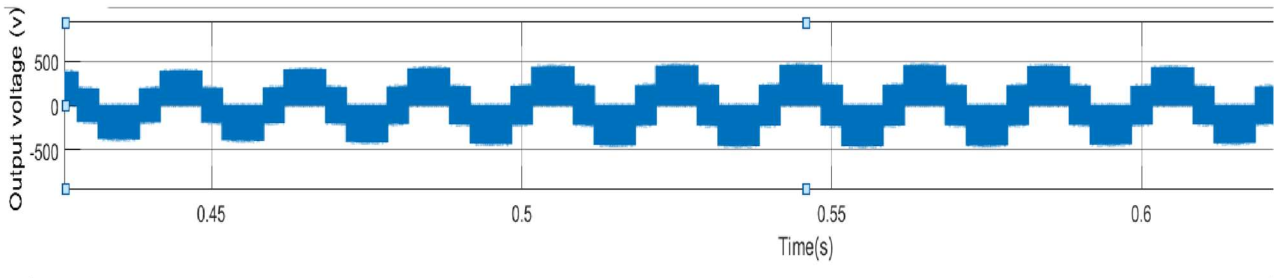

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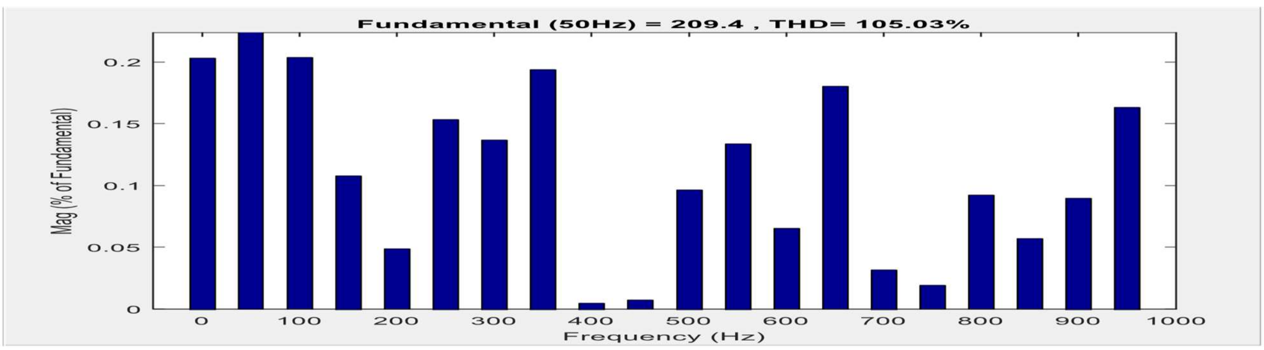
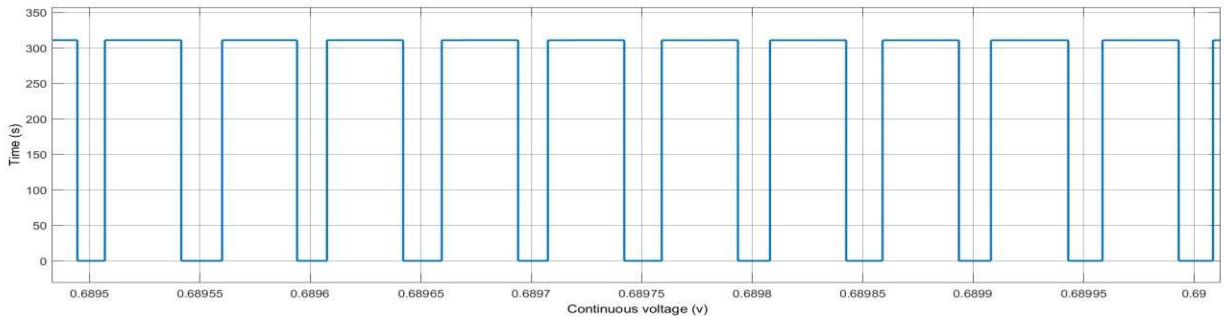


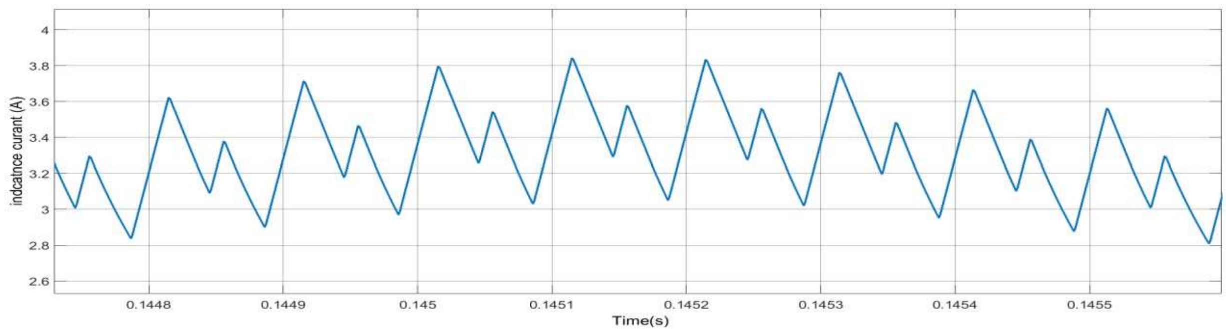
(d)

Figure (3-5): Simulation results MBC (a) Vdc-Vcz & Vg Voltages ;(b; c zoom) Inductance current ;(d) Van & V1cf voltages; (e) THD *(m = 0.7)*

With modulation index (M = 0.8)



(a)



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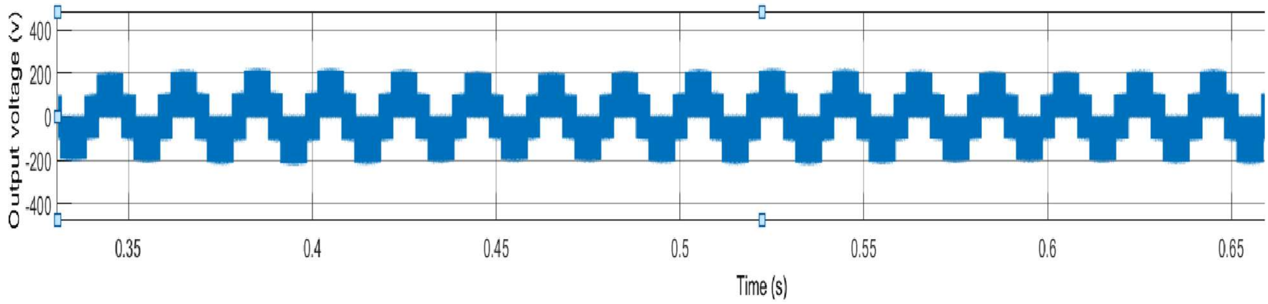

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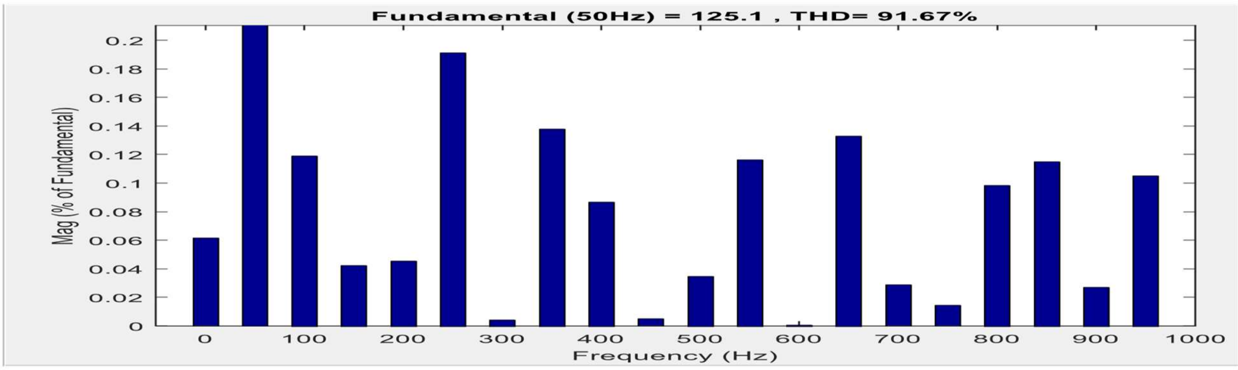
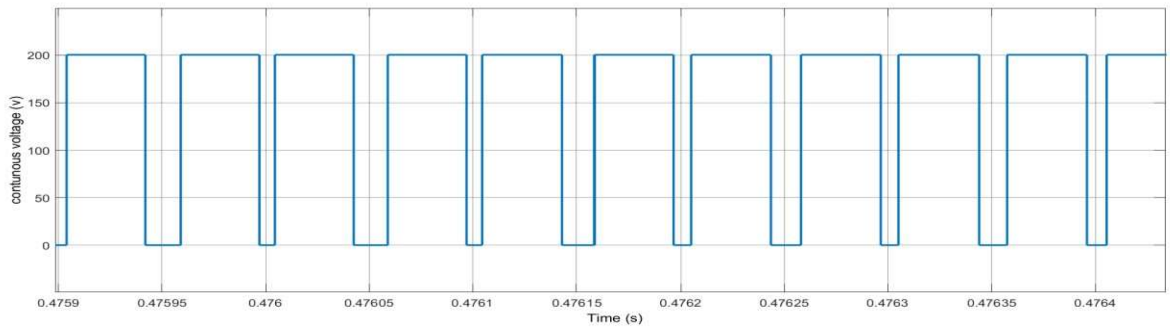


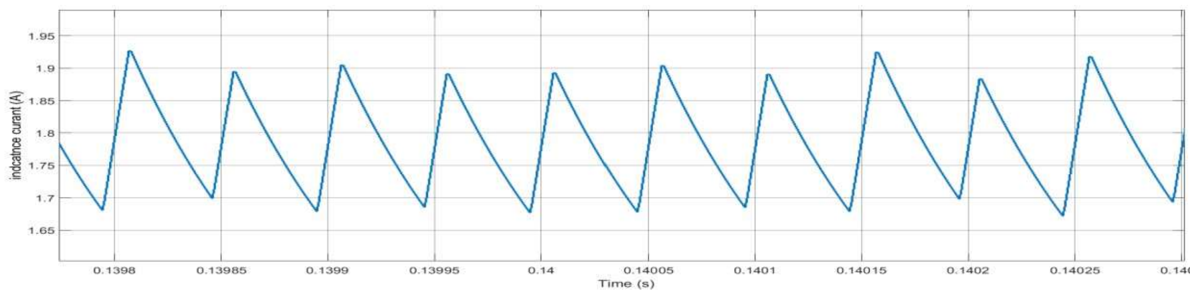
(d)

Figure (3-6): Simulation results MBC (a) Vdc-Vcz & Vg Voltages ;(b ;c zoom) Inductance current ;(d) Van & V1cf voltages; (e) THD *(m = 0.8)*

With modulation index (M = 0.9)



(a)



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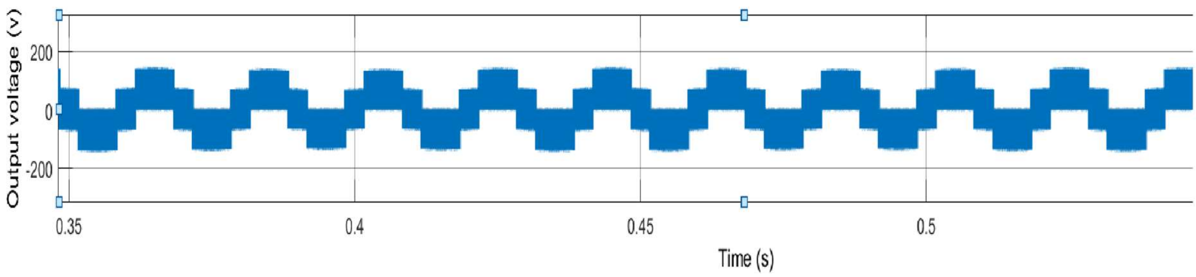

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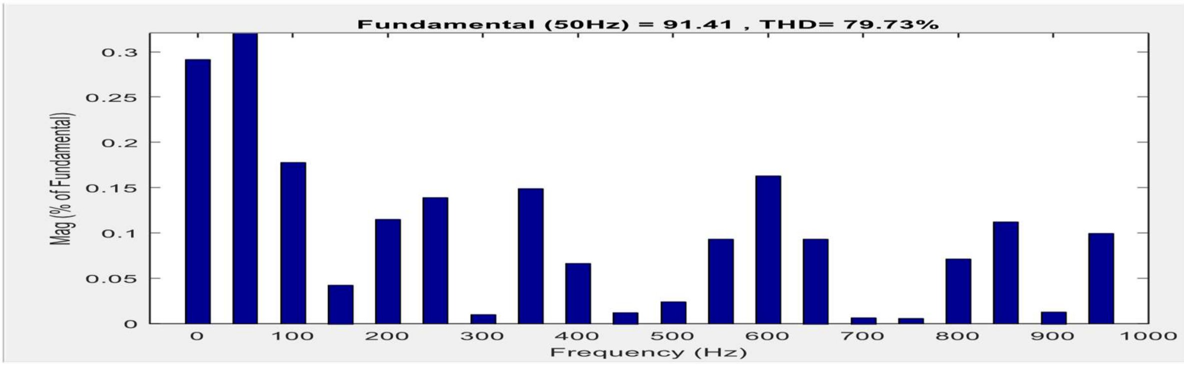
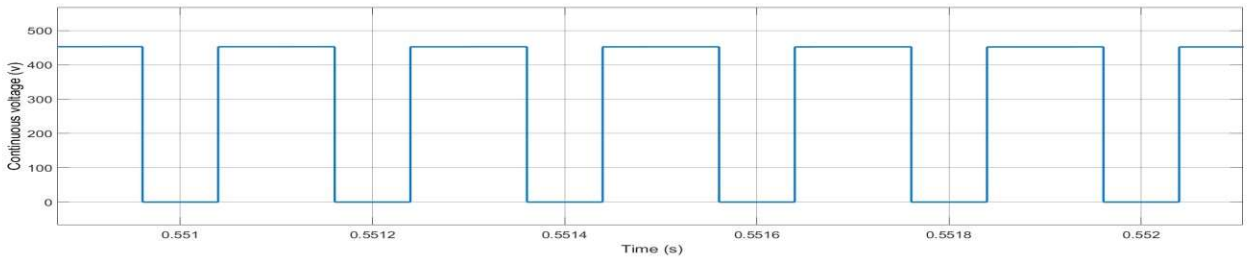


(d)

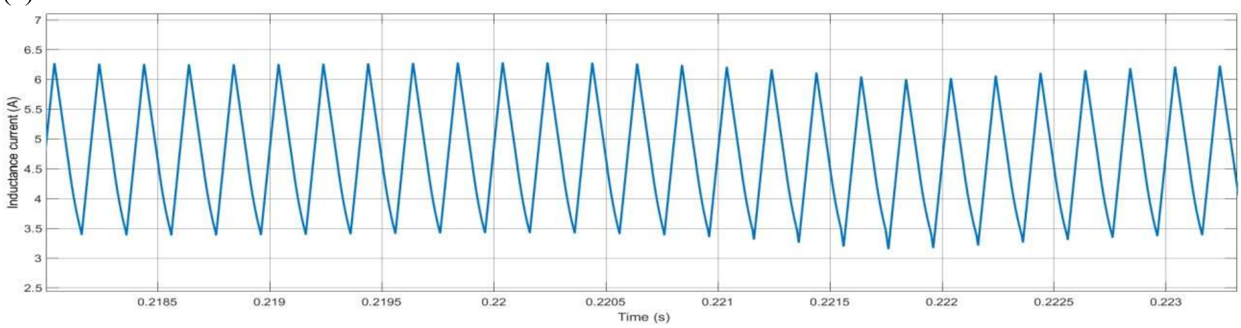
Figure (3-7): Simulation results MBC (a) Vdc-Vcz & Vg Voltages ;(b; c zoom) Inductance current ;(d) Van & V1cf voltages; (e) THD (m = 0 .9)

3.2.3. Maximum Constant Boost Control

With modulation index (M = 0.7)



(a)



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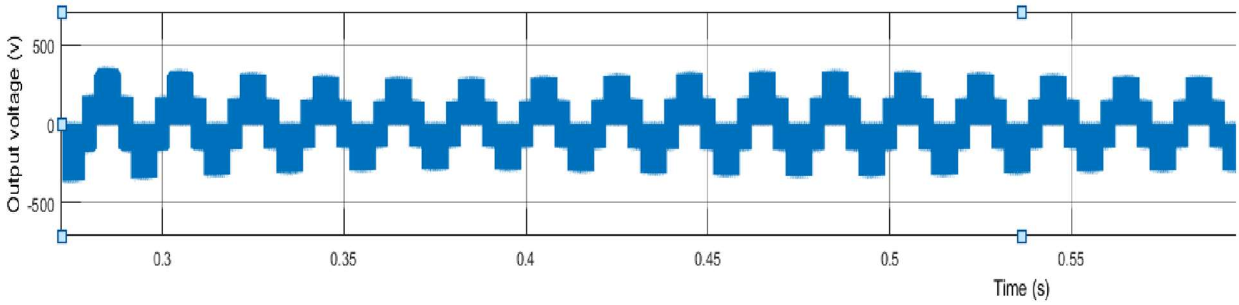

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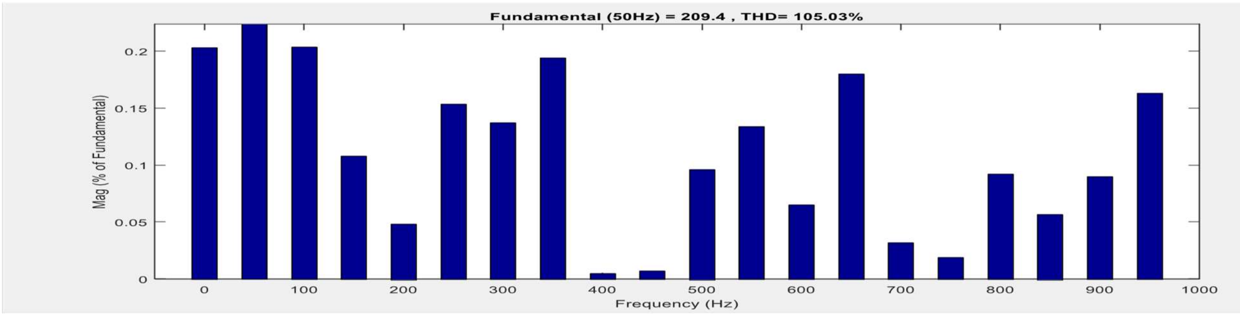
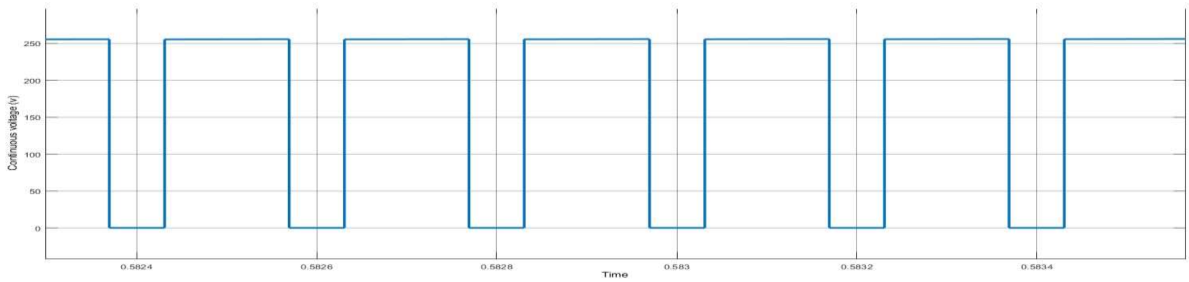


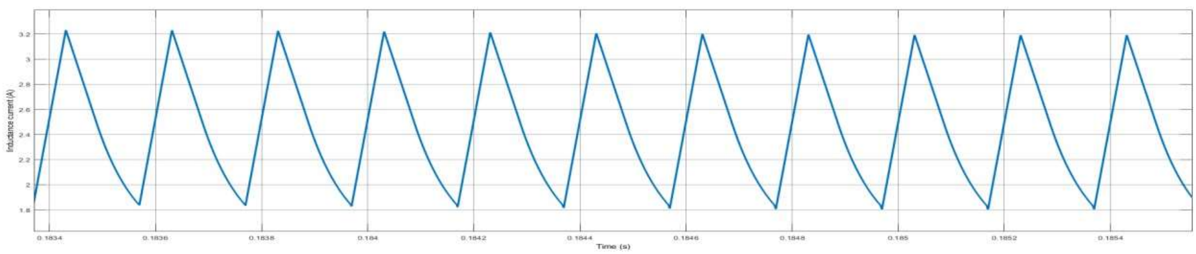
(d)

Figure (3-8): Simulation results MCBC (a) Vdc-Vcz & Vg Voltages ;(b; c zoom) Inductance current ;(d) Van & V1cf voltages; (e) THD (m=0.7)

With modulation index (M = 0.8)



(a)



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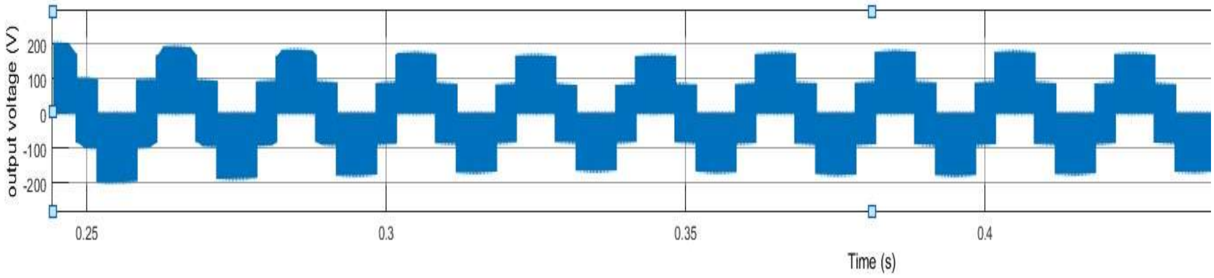

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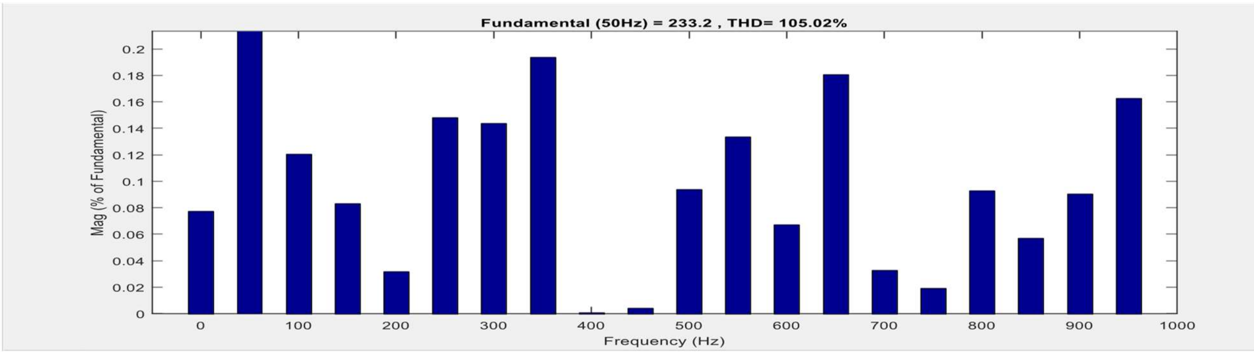
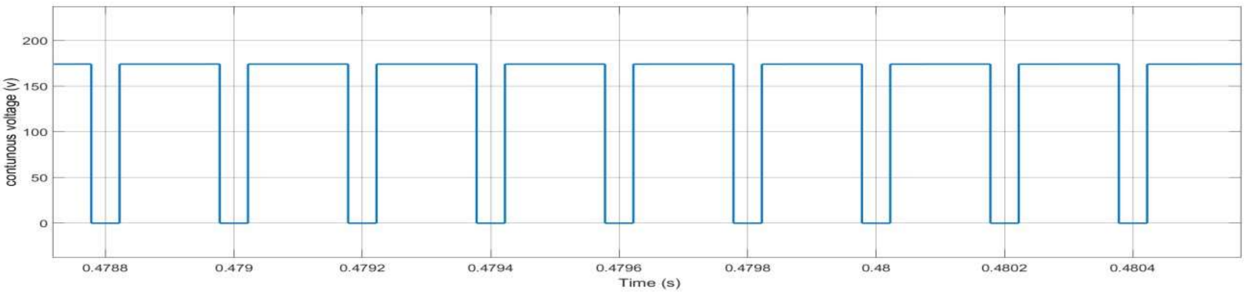


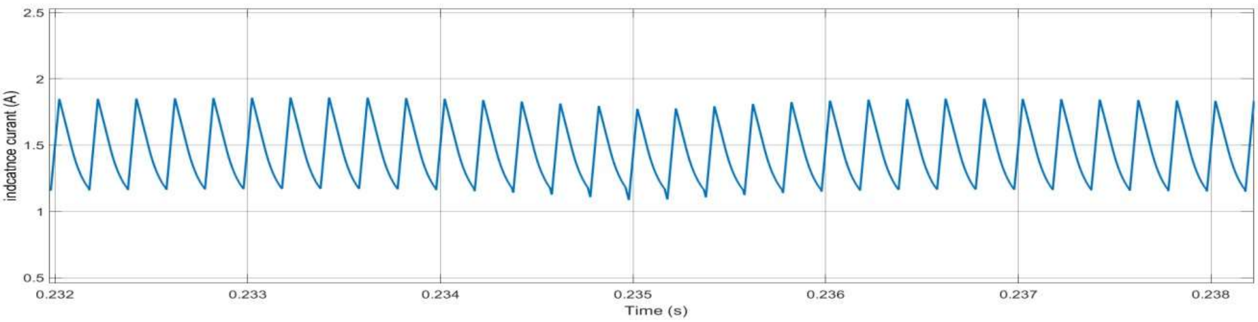
(d)

Figure (3-9): Simulation results MCBC (a) Vdc-Vcz & Vg Voltages ;(b; c zoom) Inductance current ;(d) Van & V1cf voltages; (e)THD(m=0.8)

With modulation index (M = 0.9)



(a)



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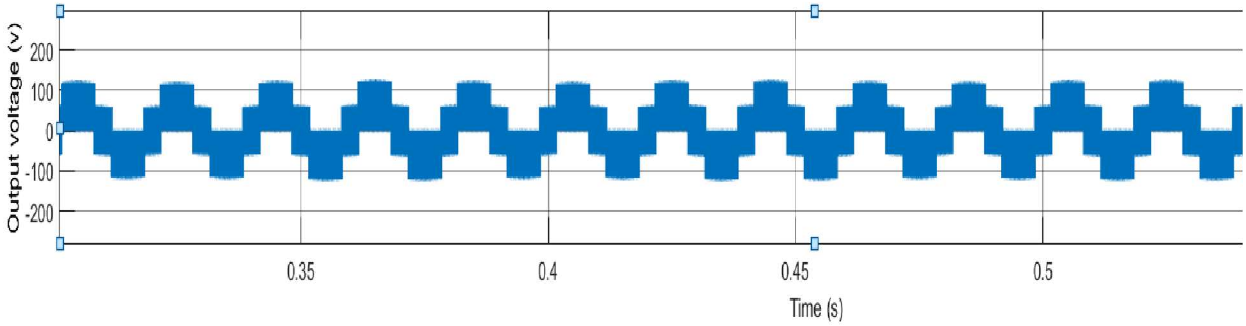

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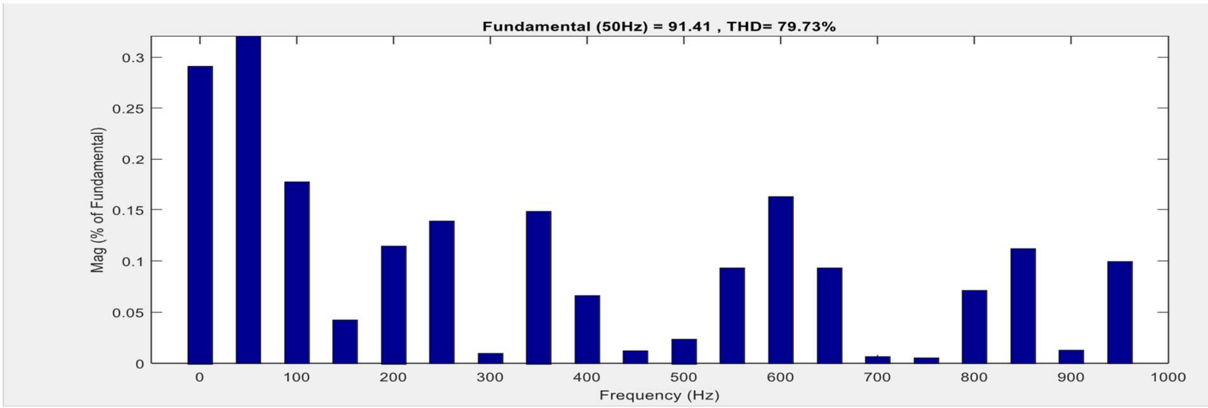

(d)

Figure (3-10): Simulation results MCBC (a) Vdc-Vcz & Vg Voltages ;(b; c zoom) Inductance current ;(d) Van & V1cf voltages; (e) THD (m=0.9)

Table (3-2): result SBC

M	0.7	0.8	0.9
V_{dc} (V)	250	170	125
V_{cz} (V)	180	110	90
$ILZmin$ (A)	1.8	1.14	0.89
$ILZmax$ (A)	2.5	1.33	0.99
Δi_{LZ}	0.7	0.19	0.1
THD (%)	104.71	91.27	79.57

Table (3.3): result MBC

M	0.7	0.8	0.9
V_{dc} (V)	610	310	200

V_{cz} (V)	490	200	180
$ILZmin$ (A)	4.9	2.85	1.68
$ILZmax$ (A)	6.5	3.85	1.93
Δi_{LZ}	1.6	1	0.25
THD (%)	105.03	91.67	79.73

Table (3.4): Result MCBC

M	0.7	0. 8	0.9
V_{dc} (V)	450	260	170
V_{cz} (V)	350	200	110
$ILZmin$ (A)	3.4	1.9	1.3
$ILZmax$ (A)	6.3	3.3	1.8
Δi_{LZ}	2.9	1.4	0.5
THD (%)	105.03	105.02	79.73

3.3. Interpretation

In this interpretation we comper this results simulation in modulation index (M= 0.7), in the following table.

Table (3.5): Simulation results summary for different PWM control methods

	SBC	MBC	MCBC
D	0.3	5.58	0 .95
G	1.75	1 .83	1.59
B	2.5	2.61	0.90
V_{cz} (V)	180	490	350
V_{dc} (V)	250	610	450
Δi_{LZ}	0 .7	1.6	2.9
THD (%)	104.71	105.03	105.03

From figure (3.2) to figure (3.10) present the different simulation results of SBC, MBC, MCBC respectively.

From the tables (3-2), (3-3) and (3-4), it can be seen that the continuous voltage (v) has high ripple due to the variation of the shoot-through duty cycle in the MBC strategy. In this case, the Z source impedance of the circuit requires a higher continuous voltage value. In both SBC and MCBC strategies, in addition to the modulation index and the voltage gain of the Z-source inverter in the MBC method at the boost factor B=2.61, G=1.83 and D=5.58 were calculated in the table (3.5). As shown, the modulation index of this control method is greater than the SBC and MCBC method. Therefore, the MBC method has a higher voltage gain.

3.4. Comparative Study

Despite the simplicity of this direct method (SBC), results are obtained, the voltage stress on the switch is relatively high V_{dc} what will Limits the realized voltage gain. Therefore, the MBC is suitable for applications with fixed or higher performance frequency. The MCBC, SBC methods allow minimizing Fluctuations in Inductance Current MCBC and SBC methods allow minimizing. However, the MCBC has the best THD which confirm the efficiency of this strategy the voltage gains and the boost factor of the MCBC the best compared to SBC and MBC.

The SBC method as we seen before has a remarkable simplicity and the MBC offer a very high boost factor.

3.5. CONCLUSION

Given the same input voltage, modulation index M and Z source impedance parameters, this chapter presents and compares three PWM control methods for the ZSI. These methods are based on sinusoidal and PWM control techniques of conventional two-level inverters. Each strategy has advantages and disadvantages that determine the appropriate scope for each strategy.

The comparison results of different strategies show that MCBC is the most suitable for controlling Z-source inverters. Nonetheless, the main feature of the SBC strategy is its simplicity, while the MBC strategy has a very high amplification factor.

GENERAL CONCLUSION

This work starts with a literature review on Z-source inverters. The literature review is based on the proposed use of various improved topologies proposed for the Z-source inverter, various existing control strategies, and various types and methods that can be used to control the Z-source DC bus.

In the second chapter, a comparative study of different existing control strategies is carried out. The comparative control strategies are simple boost control, maximum boost control, and maximum constant boost control. To validate the comparative study, simulations were performed in MATLAB/SIMULINK. Under the same input voltage, modulation index m and Z source impedance parameters, these methods are based on sinusoidal and vector PWM control techniques. SBC technique has a limited shoot-through duty ratio and voltage gain. A small modulation index must be utilized to generate an output voltage with a higher gain. Therefore, this technique cannot be used to get higher gain with a small shoot-through duty ratio. MBC technique has the greatest boost factor and voltage gain compared to the other control techniques. Therefore, to get a maximum voltage gain, this technique can be employed in ZSIs.

The only drawback of this technique is the periodic variation of the shoot-through state and accordingly the increase in inductance size to overcome the low-frequency ripples. MCBC technique has a much higher boost factor and voltage gain than the simple boost control but slightly lower than the maximum boost control. The main difference of this technique is to get a higher voltage gain with a constant shoot-through state due to the upper and lower envelope signals Each strategy has advantages and disadvantages that determine the appropriate scope for each strategy.

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Abstract

This dissertation presents a study about the z-source inverter. It contains the study of the different control strategies used for the control of the z-source inverter. The control strategies studied in this work are as follow: Simple boost control SBC, Maximum boost control MBC and Maximum constant boost MCBC. A simulation using MATLAB/Simulink is carried out to verify the control strategies, and to compare between them in terms of current ripple, output voltage, current and their harmonic curves. In addition to the shoot-through state on the Z-source network to achieve optimal efficiency.

Key words: Z-source inverter, Shoot-through (ST), Control strategies. Boosting methods, Voltage mode control, Simple boost control.

ملخص:

تقدم هذه المذكرة دراسة حول معاكس المصدر z. يحتوي على دراسة استراتيجيات التحكم المختلفة المستخدمة للتحكم في عاكس المصدر z. استراتيجيات التحكم التي تمت دراستها في هذا العمل هي كما يلي: التحكم البسيط في التعزيز SBC، الحد الأقصى للتحكم في التعزيز MBC والحد الأقصى من التعزيز المستمر MCBC. يتم إجراء محاكاة باستخدام MATLAB/Simulink للتحقق من استراتيجيات التحكم، وللمقارنة بينها من حيث التموج الحالي، والجهد الناتج، والتيار ومنحنياتها التوافقية. بالإضافة إلى ذلك، يركز على تأثير حالة قصر الدارة على شبكة المصدر Z لتحقيق الكفاءة المثلى.

الكلمات المفتاحية: المحول العكسي Z-SOURCE، الدارة المستقصرة، إستراتيجيات التحكم (PWM). طرق الرفع من الفولطية. التحكم في الفولطية. تحكم بسيط في التعزيز

Résumé

Ce mémoire présente une étude sur l'onduleur z-source. Il contient l'étude des différentes stratégies de contrôle utilisées pour le contrôle de l'onduleur z-source. Les stratégies de contrôle étudiées dans ce travail sont les suivantes : Simple contrôle boost SBC, Maximum boost control MBC et Maximum constant boost MCBC. Une simulation avec Matlab/Simulink est effectuée pour vérifier les stratégies de contrôle et les comparer en termes d'ondulation de courant, de tension de sortie, de courant et de leurs courbes harmoniques. En outre l'état de court-circuit (ST) sur le réseau Z-source pour atteindre une efficacité optimale.

Mots clés : Onduleur Z-source, Shoot-through (ST), Control stratégies, Méthode de sur voltage, Méthode de stimulation. Simple contrôle boost