# Design and Analysis of DC-DC PWM Converter and DC-AC Converter

**A Thesis Submitted to the Department of Electrical and Electronic Engineering of BRAC University**


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# Declaration

We do hereby declare that the thesis titled “Design and Analysis of DC-DC PWM Converter and DC-AC Converter” is submitted to the Department of Electrical and Electronics Engineering of BRAC University in partial fulfillment of the Bachelor of Science in Electrical and Electronics Engineering. This is our original work and was not submitted elsewhere for the award of any other degree or any other publication.

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Finally, we would like to thank each other. None of us alone could have accomplished the work. Working with the team was always a privilege. Hope our hard work pays off in helping solve the country's problem and we can provide more to the country and to the world.

# Abstract

Converters are electrical circuits that converts a voltage level to another. Inverter is used in different purposes of lives. DC-DC converters are also known as switching converters, switching power supplies or switches. DC-DC converters are important in portable device such as cellular phones and laptops. Why do we need DC-DC converter? For example, when we want to use a device with low voltage level, if we connected the device such as laptop or charger directly to the rectified supplied from the socket at home, the device might not functioning properly or it might be broken due to over current or overvoltage. Therefore, to avoid unnecessary damage to the equipment and devices, we would need to convert the voltage level to suitable voltage level for the equipment to function properly. Inverters are required in a variety of applications including electronic ballasts for gas discharge lamps and electrosurgical generators. Induction heater is another field where inverter is needed. It is one of the popular techniques of producing high temperature. Pulse Width Modulation or PWM technology is used in Inverters to give a steady output voltage of 230 or 110 V AC irrespective of the load. The Inverters based on the PWM technology are more superior to the conventional inverters. The use of MOSFETs in the output stage and the PWM technology makes these inverters ideal for all types of loads. Pulse width modulation is the process of modifying the width of the pulses in a pulse train direct proportion to a small control signal; the greater the control voltage, the wider the resulting pulses become. PWM inverters are among the most used power-electronic circuits in practical applications. These inverters are capable of producing ac voltages of variable magnitude as well as variable frequency. The quality of output voltage can also be greatly enhanced, when compared with square wave inverters. The PWM inverters are very commonly used in adjustable speed ac motor drive loads where one needs to feed the motor with variable voltage, variable frequency supply. For wide variation in drive speed, the frequency of the applied ac voltage needs to be varied over a wide range. The applied voltage also needs to vary almost linearly with the frequency. PWM inverters can be of single phase as well as three phase types.

# Chapter 1

# Introduction

## 1.1 Project Background

In modern days, most of the inverters use PWM technology to produce AC output from DC input or DC from DC input. The inverters constructed based on this Pulse Width Modulation technique are superior in most aspects than other inverters designed using the normal conventional design. The PWM based inverters and converters generally uses MOSFET switches in the control circuits to produce output. For this reason, the inverters and converters are considered as PWM MOSFET inverters and converters. The inverters and converters with PWM switching technology provides more security and control compared to other the regular inverters and converters. To keep the output voltage of a converter or an inverter at the rated voltage (which keeps the attached devices performing at their best) Pulse Width Modulation also known as PWM is implemented to keep the voltage constant regardless of the Load device. In a traditional converter and inverter the output voltages varies due to variation of the load. To negate the effect caused by the loads, PWM inverters and converters adjusts the values of the output so it does not hamper the device connected to the load output. This operation is gained by changing the width of the switching signal produced by the comparison of the oscillation of reference and carrier signal. The AC output at the load is determined by the switching pulse. This operation is done by using a feedback for the output to the PWM switching control section. Using this feedback the PWM controller circuit will make essential alteration in the pulse width of the switching signal created at the oscillator part. This variation in the pulse width of the switching signal will terminate the changes in the output voltage and the inverter or converter output will stay constant regardless of the load changes.

## 1.2 Motivation

Today is the world of technology. People are discovering every now and then. DC-DC converter has wide variety of uses. Most DC to DC converter circuits also control the output voltage. Some exemptions include high-efficiency LED power sources, which are a kind of DC to DC converter that regulates the current through the LEDs, and simple charge pumps which double or triple the output voltage. DC to DC converters developed to maximize the energy harvest for photovoltaic systems and for wind turbines are called power optimizers. Transformers used for voltage conversion at mains frequencies of 50–60 Hz must be large and heavy for powers exceeding a few watts. This makes them expensive, and they are subject to energy losses in their windings and due to eddy currents in their cores. DC-to- DC techniques that use transformers or inductors work at much higher frequencies, requiring only much smaller, lighter, and cheaper wound components. Consequently, these techniques are used even where a mains transformer could be used; for example, for domestic electronic appliances it is preferable to rectify mains voltage to DC, use switch-mode techniques to convert it to high-frequency AC at the desired voltage, then, usually, rectify to DC. The entire complex circuit is cheaper and more efficient than a simple mains transformer circuit of the same output.

### 1.3 Equipment and Software

For this thesis, we used the equipment given below-

- LF411 (Op-Amp)
- IRF150 (MOSFET)
- Resistance – 1K & 2.5KΩ
- Capacitor
- Inductor

**For circuit design and simulation, we used Pspice schematics software.**

# Chapter 2

# Switching Converter Topologies

## 2.1 Introduction to the Converters

Converter in power electronics converts power from one type to another by varying the voltage or frequency. Power conversion relies on type of the input and output power. Converter driven applications are widely used. Many wind-farm, ship drives, several boiler feed water pumps and many other applications operate much more efficiently and economically in case of variable speed solutions. The boundary conditions for a motor and generator will change if a converter supplies it.

## 2.2 Types of Converters

There are several types of converters. In general, there are four types of converter depending on their input and output power. Those are:

1) AC to DC converter (rectifier)
2) DC to DC converter
3) AC to AC converter
4) DC to AC converter (inverter)

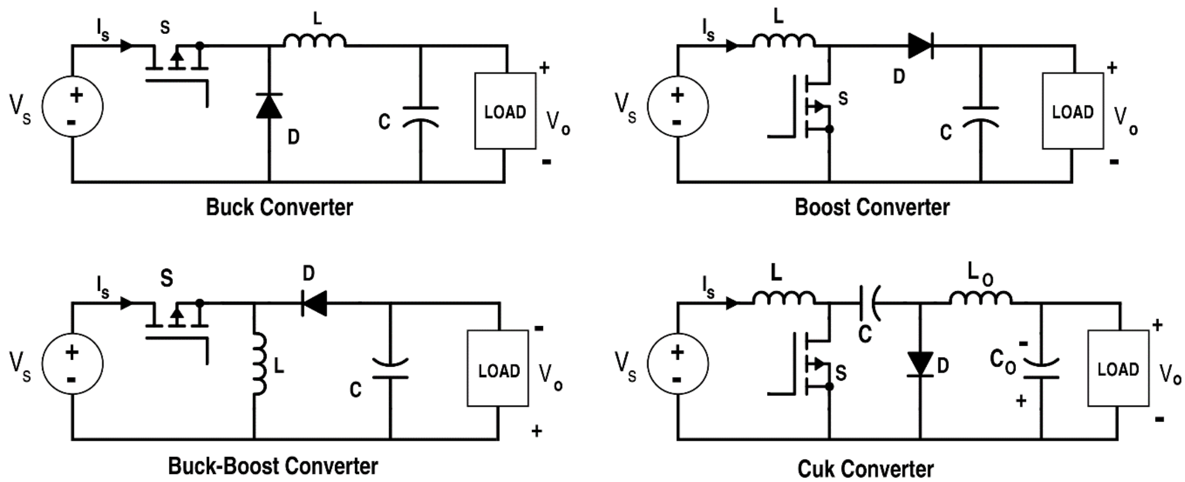
In this paper, we will talk about only DC-to-DC converter in the first half and in the second half, we will talk about DC-AC converters.

## 2.3 DC to DC converter

A DC-to-DC converter converts a source of dc voltage to a different voltage level. A DC-to-DC converter is a widely used converter. It has several uses, such as in cellular mobile phones and laptop because their supply primarily comes from the batteries. For several uses, there are different types of DC-to-DC converter. Here some are given:

i) Buck Converter
ii) Boost Converter
iii) Buck-Boost Converter

iv) Cuk Converter




**2.4 A basic switching converter**

In a switching converter transistor operates as a switch by being fully on or off.

**2.5 Introduction to the DC-AC Converter**

A DC-AC Converter transforms a DC voltage to an AC voltage. Usually the DC voltage is lower than AC voltage, which varies with countries like Bangladesh which grid supply voltage is 220V.

There are several uses of DC-AC Converter. In present world, DC-AC Converter is widely used. In our day-to-day life, it has a big impact. Appliances, which uses batteries primarily, in such cases inverters, are mostly used. Such as in solar panel, fuel cells etc.

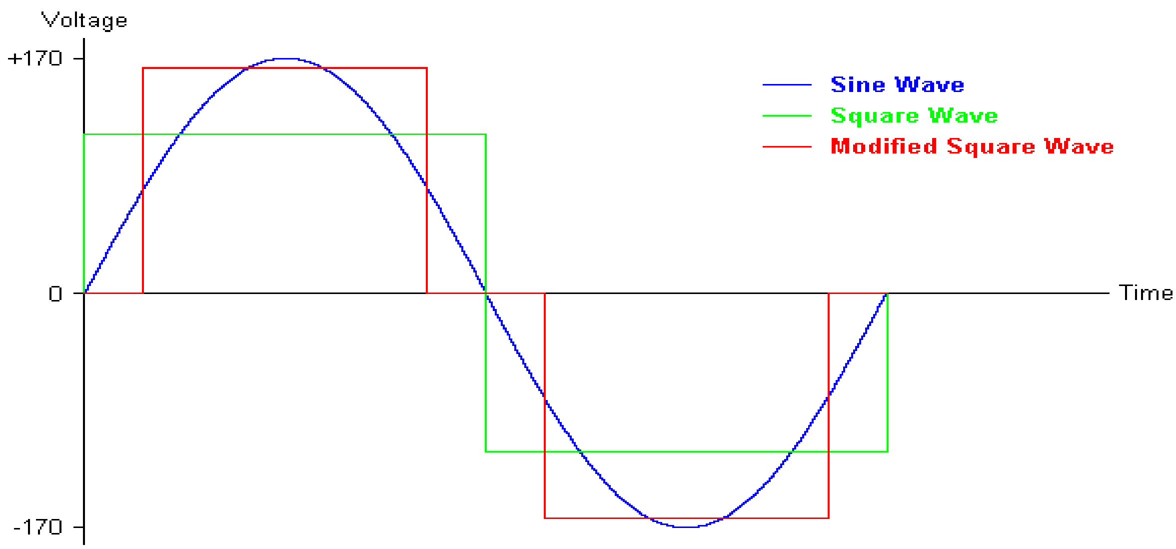
**2.6 Types of DC-AC Converter**

In general, there are three important types of DC-AC Converter. These DC-AC Converters are categorized based on their working principle. Several DC-AC Converter has several characteristics and working principle. Now, those three DC-AC Converter are:

i) True or Pure Sine Wave DC-AC Converter
ii) Modified Sine Wave or Quasi Sine Wave DC-AC Converter
iii) Square Wave DC-AC Converter

### 2.6.1 True or Pure Sine Wave

Usually we get sine wave from local utility company. As because power development board generate power from AC machineries. It's always needed for a grid supply system. In comparison with modified sine wave inverter, pure sine wave DC-AC Converter is slightly expensive. Usually what we get in the market is designed for a sine wave. There are many uses of pure sine wave DC-AC Converter. For instance, motors and microwave ovens are fully operate in pure sine wave condition.




### 2.6.2 Square Wave DC-AC Converter:

Square wave i DC-AC Converter is considered the simplest type of DC-AC Converter that converts dc signal into an AC signal. It is also very cheap and can be made using just a on and off switch. Despite of being the simplest type, one of the major problem with this type of DC-AC Converter is that the output is not pure AC. Square wave DC-AC Converter can be used only for small and light applications. If used for heavy applications, the appliance might be damaged.

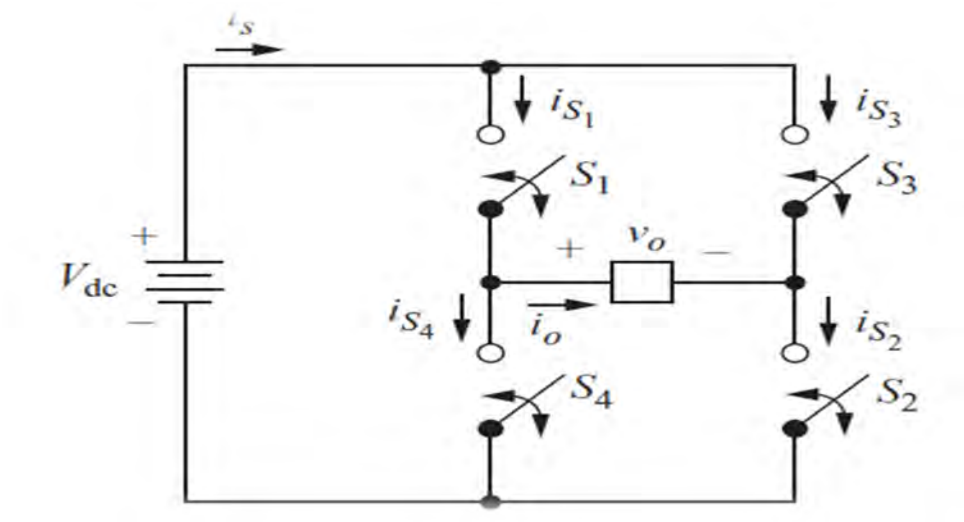



Fig 2.6.3: Square Wave

### 2.6.3 Modified Sin Wave DC-AC Converter:

Modified sin wave is in between pure sin wave and square wave. Before phase changing, we can see some pauses and series of steps. These type of DC-AC Converters are easy to create than pure sine wave inverts and less expensive also.  Typical resistive loads can be run easily but there are many devices that may not run. THD is also higher and devices may get hotter and are damaged if modified sin wave is used to run them.

## 2.7 Pulse Width Modulation (PWM):

Pulse Width Modulation (PWM) is a technique through which the total harmonic distortion (THD) of load current can be reduced. After using some filter, the total harmonic distortion of the PWM inverter output will reduce significantly meeting the requirements. A pure sin wave is obtained after passing the signal through a low pass filter.  In power electronics, PWM is used for various purposes. Primarily where there is a DC source, PWM is used to power alternating current devices and for advanced DC-to-AC conversion. By modulating the waveforms of the PWM, the amplitude of the output can be controlled. Those are two major advantages of PWM. More specifically reduced THD and controlled of the output voltage are two benefits of PWM. On the contrary it has more complex switching scheme and hence losses increased because of frequent switching. Therefore, sinusoidal PWM output needs a reference signal, which is sine wave, and a carrier signal, which is triangular wave that controls the switching frequency.

### 2.8 PWM Definitions:

In PWM generation two very important factors are frequency modulation and amplitude modulation ratio.

**2.8.1 Frequency Modulation Ratio, mf**:

The ratio of the frequencies of the carrier and reference signals is defined as the frequency modulation ratio. There are some harmonics, which are larger than the fundamental, as because they are in high frequencies a low pass filter might be effective to eradicate them. By increasing the carrier frequency, can increase the frequencies at which harmonics occur.

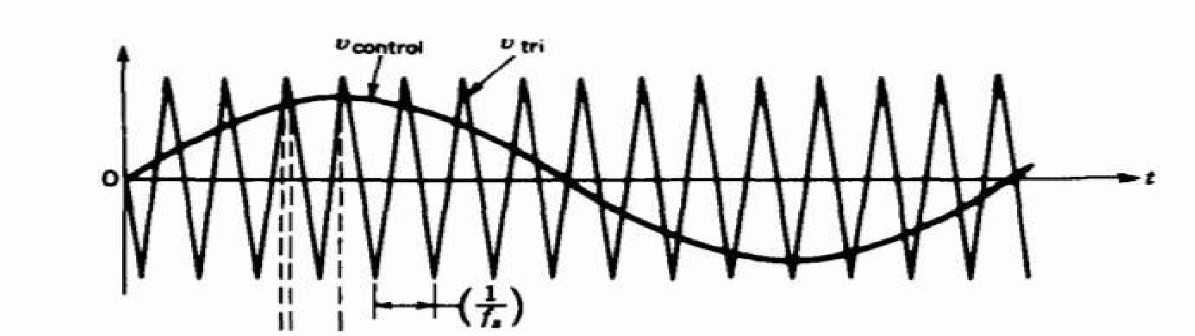
$$mf = \frac{fcarrier}{freference} = \frac{ftriangular}{fsine}$$

**2.8.2 Amplitude Modulation Ratio, ma:** the ratio of the amplitudes of the reference and carrier signals is defined as the amplitude modulation ratio.

$$ma = \frac{Vm, reference}{Vm, carrier} = \frac{Vm, sine\ or\ Vm, control}{Vm, triangilar}$$

. If *ma* ≤1, the amplitude of the fundamental frequency of the output voltage *V*o is linearly proportional to *ma*. That is,

$$Vo = maVdc$$



### 2.9 Bipolar and Unipolar Sinusoidal Pulse Width Modulation Techniques:

### 2.9.1 Bipolar PWM DC-AC Converter Techniques:

Bipolar inverters works from peak to peak. Simultaneously both positive and negative pulses can be generated from the circuit. The upper and the lower switches in the identical inverter leg work in a balancing manner with one switch turned on and other turned off. In bipolar switching scheme, carrier and modulating signal are compared [1]. The inverter switches are turned on whenever the reference signal is larger than the carrier signal and vice versa [1]. The PWM output then exhibits odd symmetry, and the Fourier series can then be expressed

$$vo(t) = \sum_{n=1}^{\infty}(V_n \sin(nw_0 t))$$

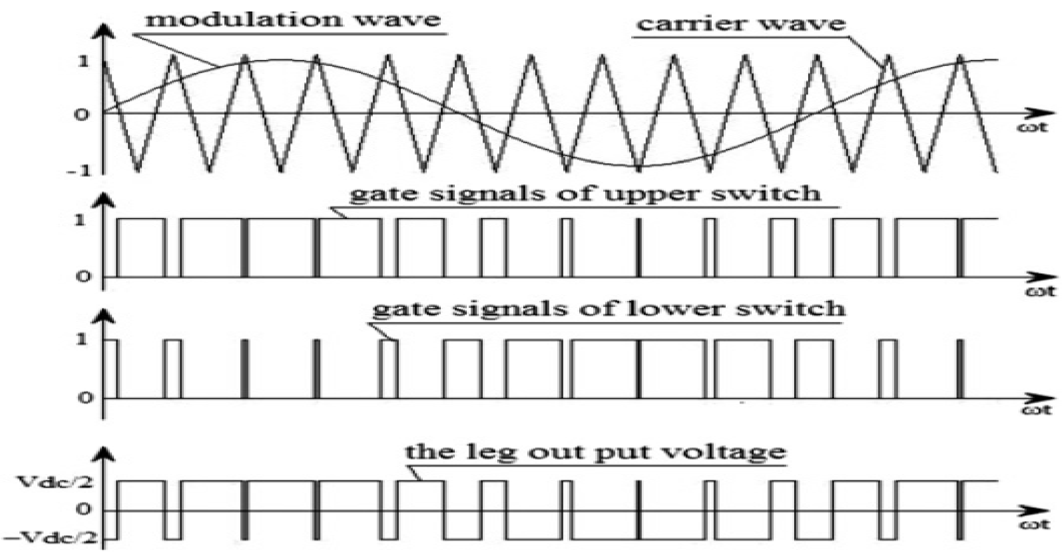



Fig 2.9.1: Bipolar PWM Technique

### 2.9.2 Unipolar PWM DC-AC Converter Techniques:

In general, the unipolar modulation needs two sinusoidal modulation waves with identical frequency and magnitude and 180º phase shift. The two sinusoidal signals are compared with same triangular wave [1]. The inverter output voltage does not switches simultaneously, what has happened in bipolar techniques. During positive half cycle, it switches between zero and positive and for negative half cycle it switches between zero and negative. Unipolar PWM inverter much effective rather than bipolar as because it has lesser switching losses.

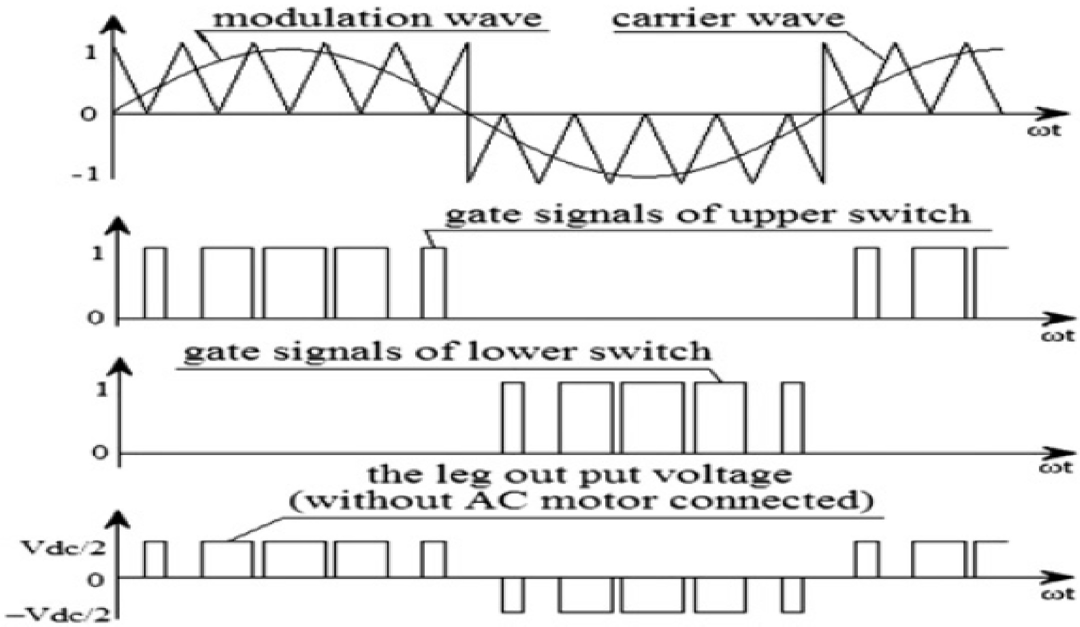



Fig 2.9.2: Unipolar PWM Technique

**2.9.3 MOSFET Driver:**

When operating N-Channel MOSFETs to switch a DC voltage through a load, the drain terminals of the high side MOSFETs are repeatedly connected to the highest voltage in the system. This creates a difficulty, as the gate terminal must be approximately 10V higher than the drain terminal for the MOSFET to conduct. Often, integrated circuit devices known as MOSFET drivers are utilized to achieve this difference through charge pumps or bootstrapping techniques. These chips are capable of quickly charging the input capacitance of the MOSFET quickly before the potential difference is reached, causing the gate to source voltage to be the highest system voltage plus the capacitor voltage, allowing it to conduct.

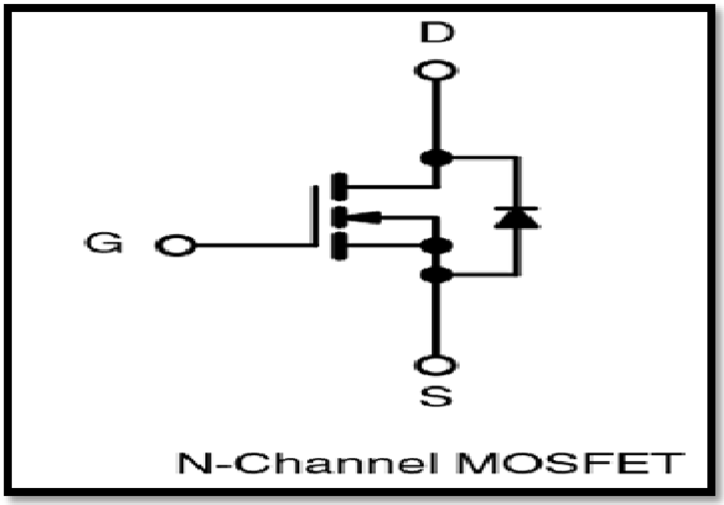



Fig 2.9.3: N Channel MOSFET

There are many MOSFET drivers available to power N-Channel MOSFETs through level translation of low voltage control signals into voltages capable of supplying sufficient gate voltage. Advanced drivers contain circuitry for powering high and low side devices as well as N and P-Channel MOSFETs. In this design, all MOSFETs are N-Channel due to their increased current handling capabilities. To overcome the difficulties of driving high side N-Channel MOSFETs, the driver devices use an external source to charge a bootstrapping capacitor connected between Vcc and source terminals. The bootstrap capacitor provides gate charge to the high side MOSFET. As the switch begins to conduct, the capacitor maintains a potential difference, rapidly causing the MOSFET to further conduct, until it is fully on.

**2.9.4 Effect of Blanking Time on Voltage in PWM Inverters:** The switching lag-time, which prevents the phase shortage of inverter arms, causes serious distortions of the output voltage of the inverter. This effect is well known as dead-time effect//Blanking time effect.

- To avoid shoot through in PWM controlled vsi a blank time is introduced
- In this period both upper and lower switches in a phase leg are off
- So that short circuit can be avoided and switches are not damaged due to high current

- Dead time varies with **i)** Devices ii) Output current **iii)** Temperature

Which makes the compensation less effective at low output current & low frequency.

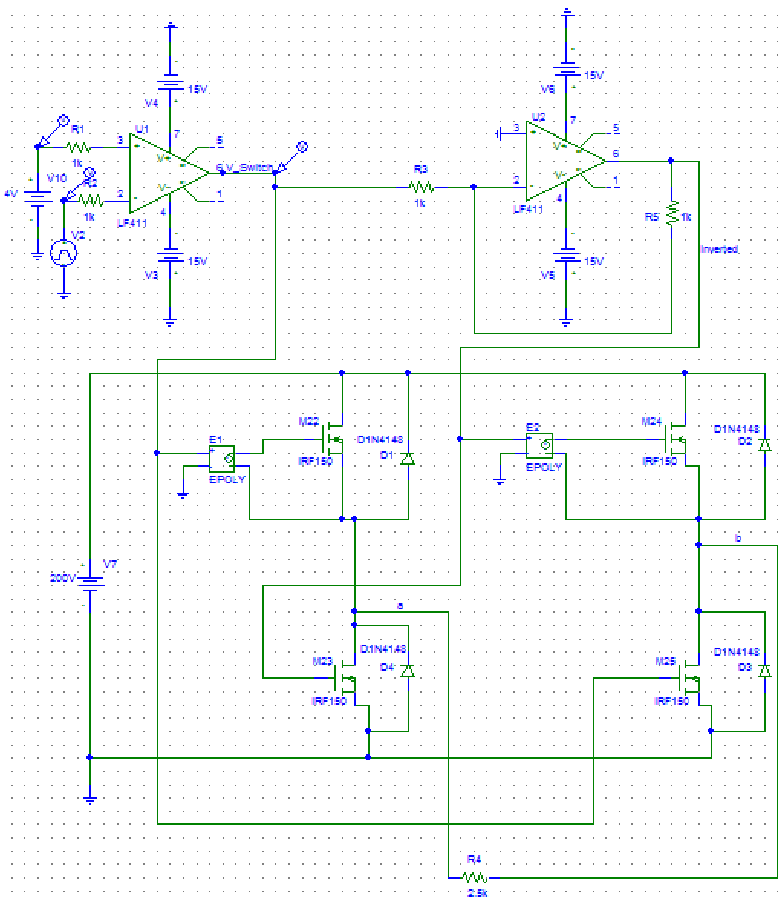
# Chapter 3

# Simulation of DC-DC PWM Converter

In this chapter, we will talk about the designs of DC DC converters that we implemented in PSpice Schematics. We will also simulate them to show the output curves and compare their performance. First, we will show bipolar dc dc converter. After that, we will change the dc reference voltage and analyze the output.

### 3.1 Bipolar DC-DC Converter

In our design, LF411 Op-Amp was used for integrating the inputs. We used VPulse to generate a triangular wave and 4V dc voltage as reference.




Properties of the Vpulse are:

| Name | Value |
|---|---|
| V1 | -5 |
| V2 | 5 |
| TD | 0ms |
| TR | 0.5ms |
| TF | 0.5ms |
| PW | .005ms |
| PER | 1ms |

Figure 3.1.1: Design of Bipolar DC-DC Converter

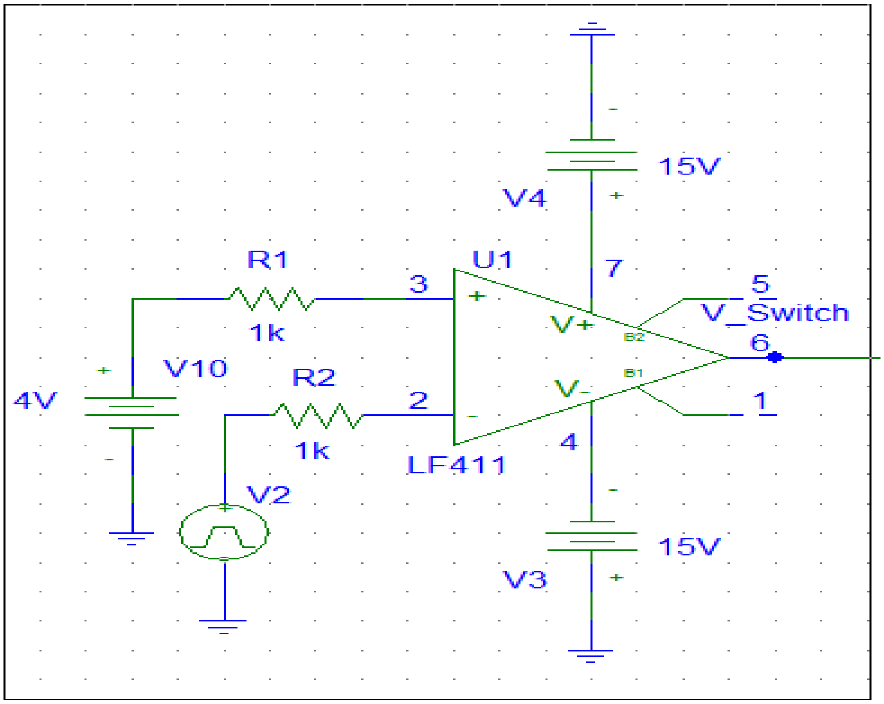



Fig 3.1.2: Signal Generation Circuit

| Vpulse Properties | Values |
|---|---|
| V1 | -5 |
| V2 | 5 |
| TD | 0ms |
| TR | 0.5ms |
| TF | 0.5ms |
| PW | 0.005ms |
| PER | 1ms |

In this circuit we used the 4V +VDC as a reference signal and the Vpulse property to generate a triangular wave to be used as a carrier wave to compare using the Op-Amp device. The signals below are generated because of this operation-

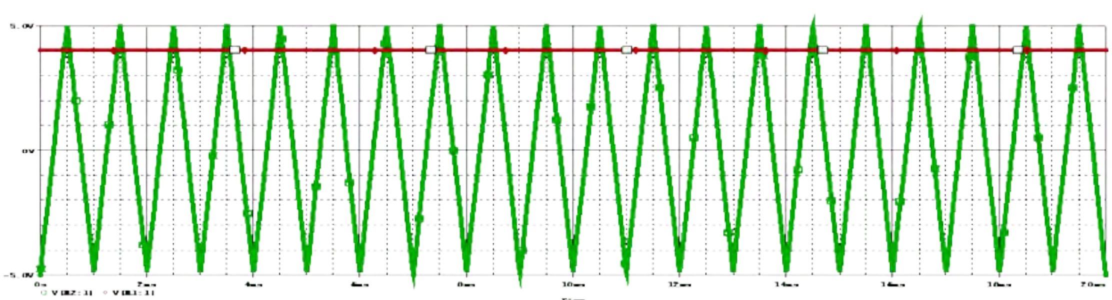


Figure 3.1.3: Input signal

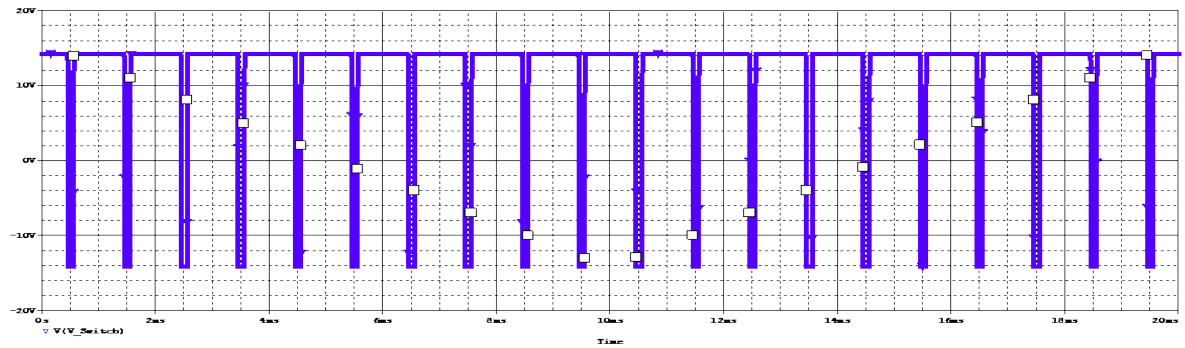



Figure 3.1.4: Switching signal

In the op-amp output pin we got a square wave of +14.283V to -14.283V. When V(tri)<V(dc), Vo = +14.283V and when V(tri)>V(dc), Vo = -14.283V. We passed this output through another op-amp to invert the output. These outputs were connected with 4 MOSFETS for switching purpose (as shown in figure 2.1). Output of the first op-amp was connected with M22 (S1) and M25 (S2). The inverted output was connected with M23 (S4) and M24 (S3). They were connected with a source voltage of 200V.

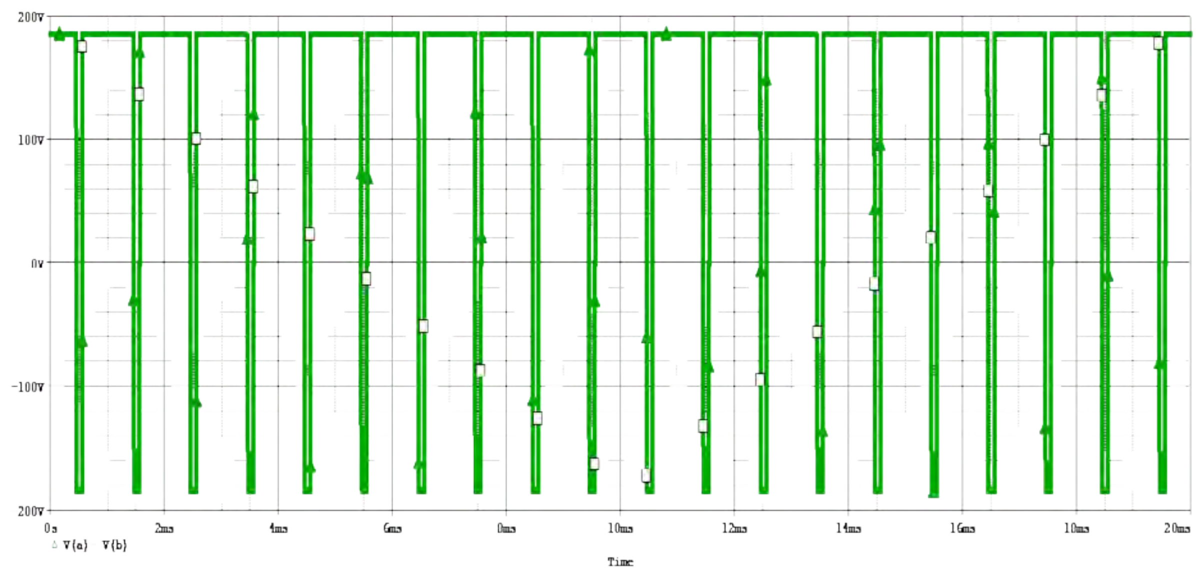



Figure 3.1.5: Output voltage of bipolar dc-dc converter.

The average of the output was found to be 146.554 V.

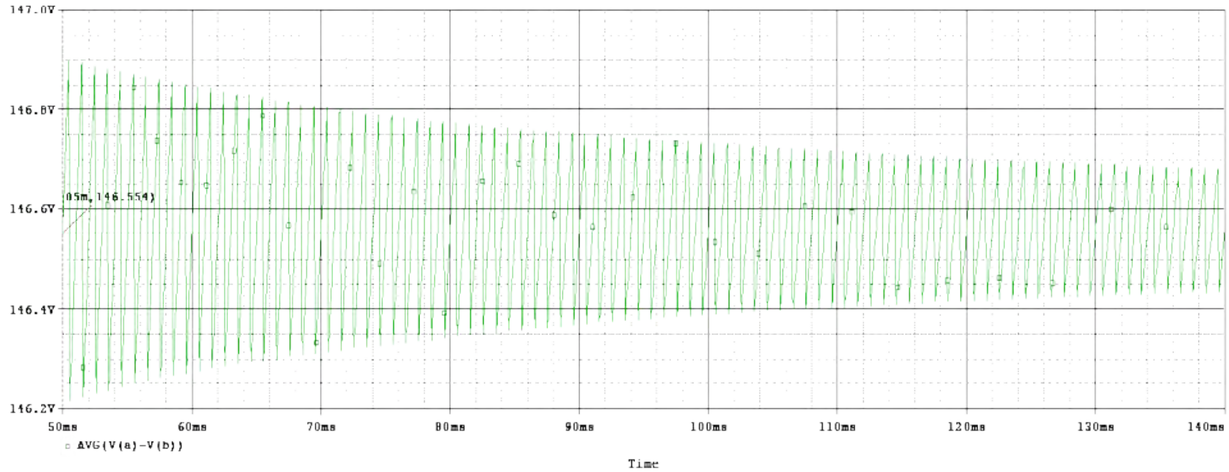



Figure 3.1.6: Average of the output voltage

We then used the same circuit and changed the reference dc voltage to -4V.

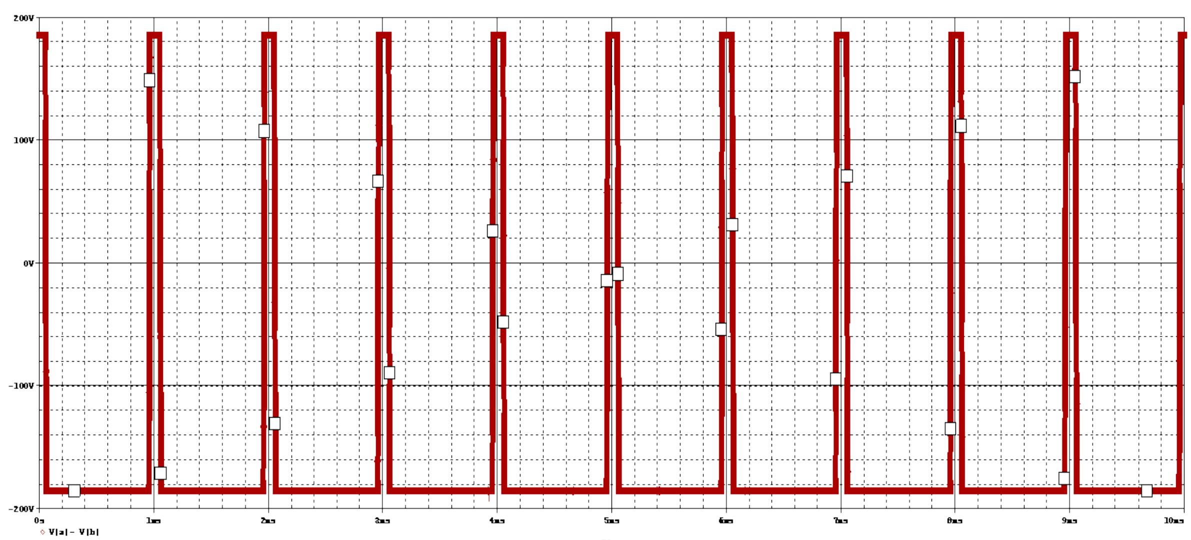



Figure 3.1.7: Output voltage using -4V Vdc

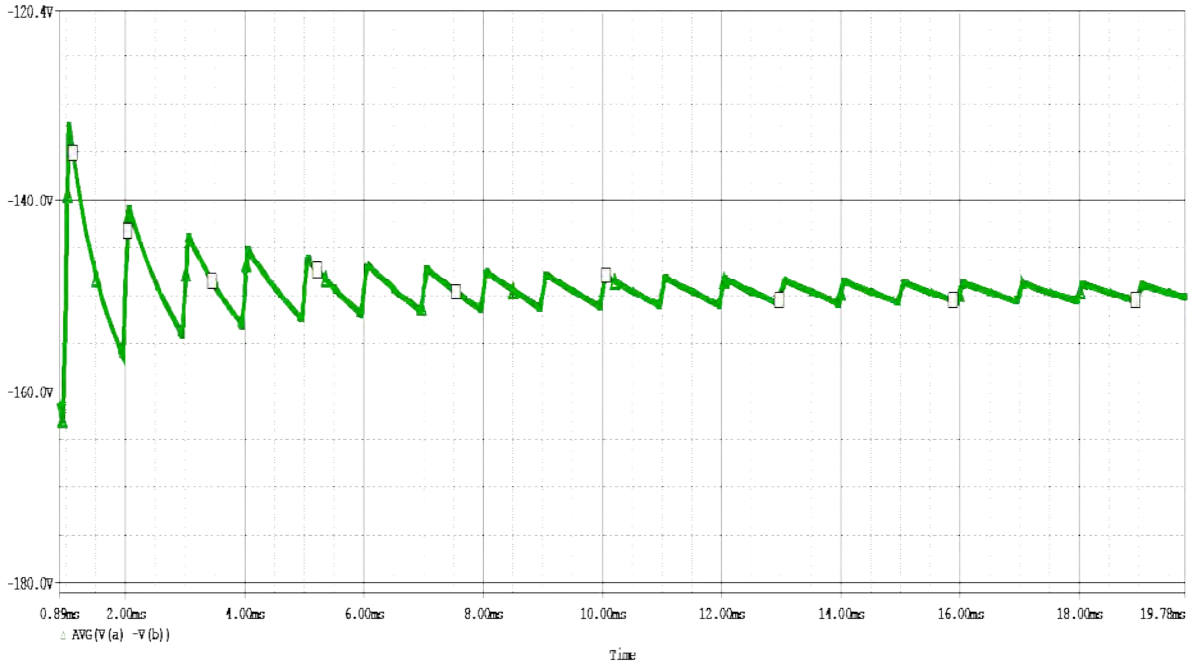



Figure 3.1.8: Average voltage using -4V Vdc

For comparing the output voltage, we decided to run the circuit with a change in voltage level of the reference Vdc. First we simulated the circuit using +1V Vdc and found that the width of the generated pulse was reduced significantly compared to the +4V Vdc input. (Figure 2.3.1)

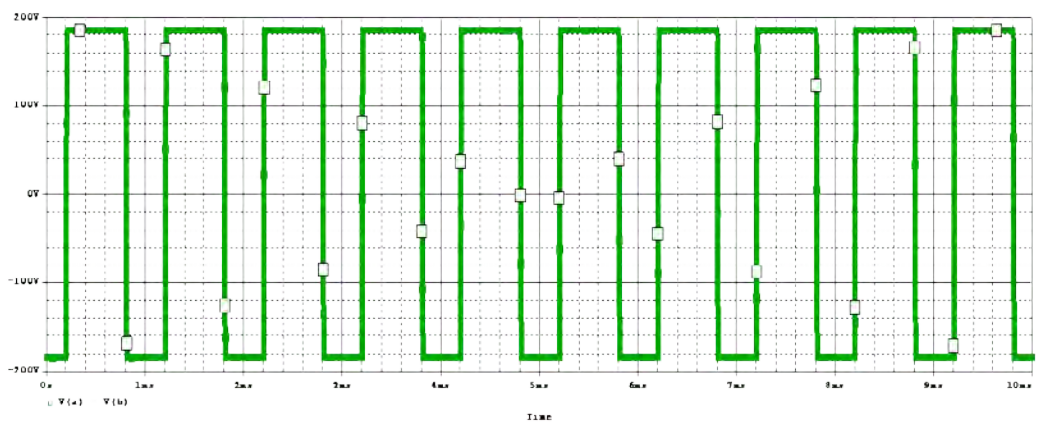


Figure 3.1.9: Output voltage using +1V Vdc

Accordingly, the Average Voltage decreases a great amount (Figure 2.3.2)

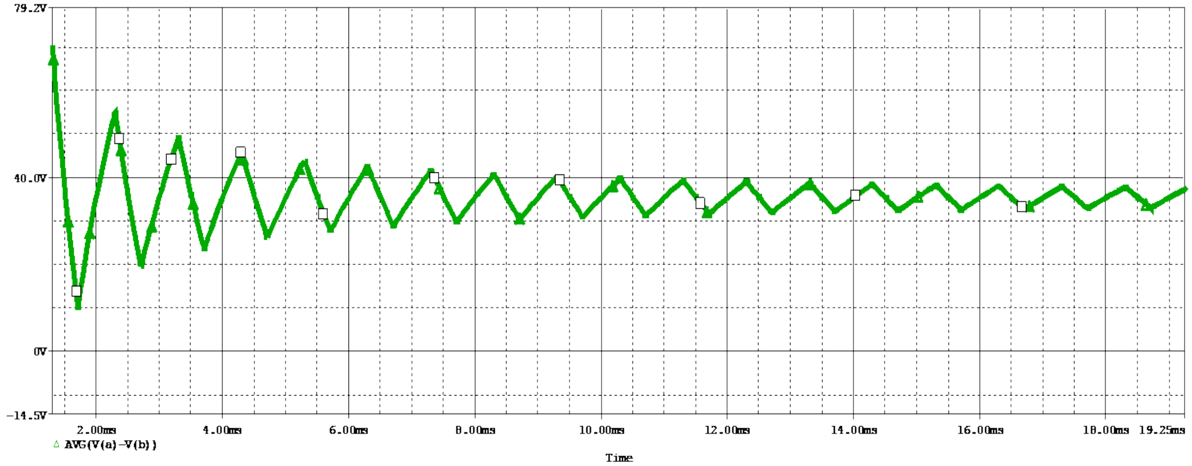



Figure 3.1.10: Average voltage using +1V Vdc

Then we simulated the circuit using +1V Vdc and found that the width of the generated pulse was reduced significantly compared to the -4V Vdc input (Figure 2.4.2).

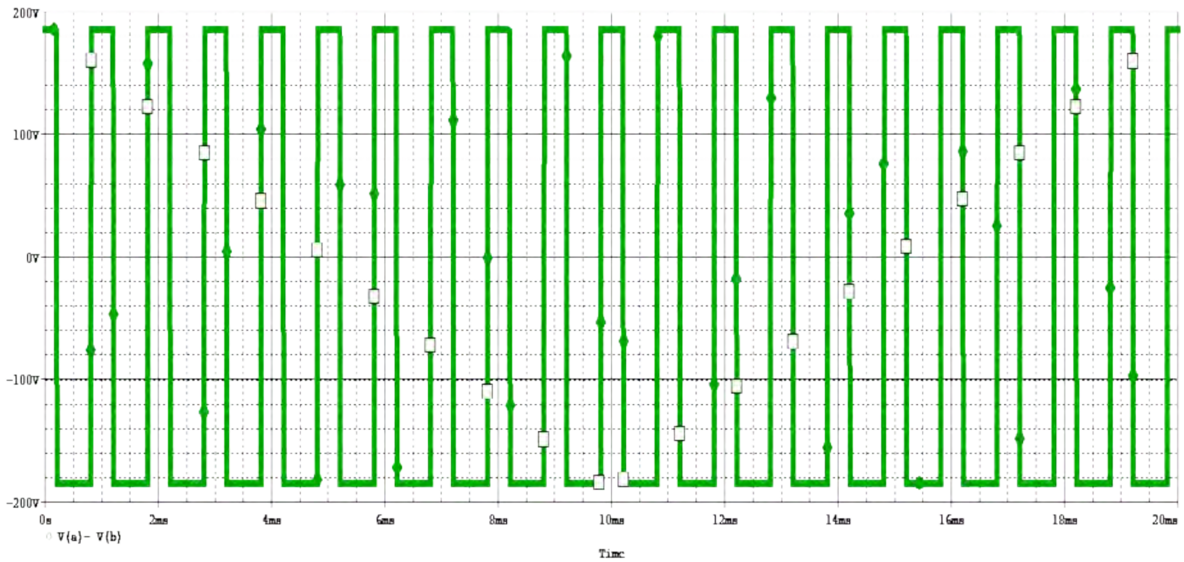



Figure 3.1.11: Output voltage using -1V Vdc

The Average of the output decreases significantly compared to the -4V Vdc. (Figure 2.4.2)

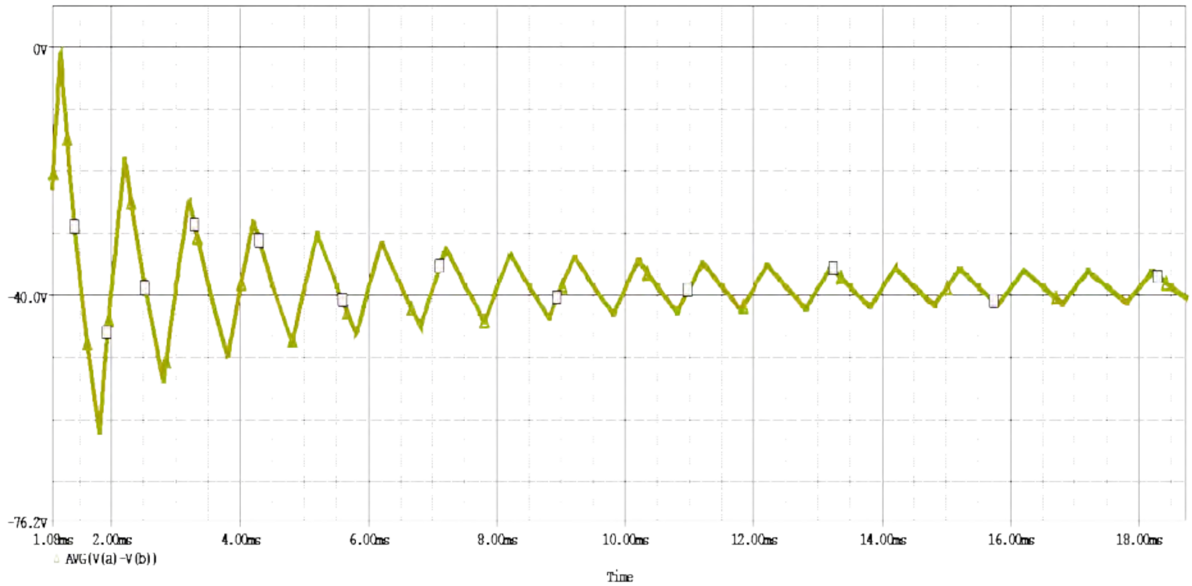
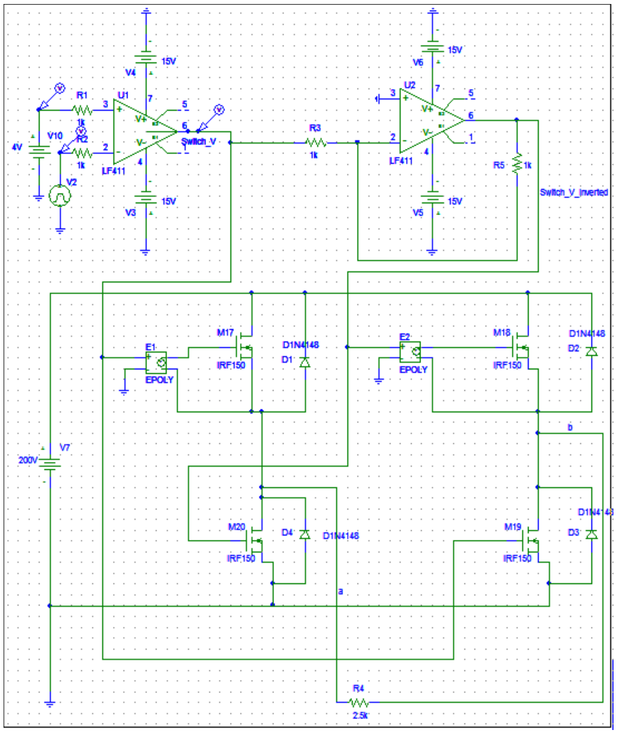



Figure 3.1.12: Average voltage using -1V Vdc

**3.2 Unipolar DC-DC Converter**

Now we want to change the carrier wave to have a different observation of the circuit's outputs. As in case of Saw Tooth signal, we get only positive signal that is why we used this in case of unipolar DC-DC Converter. In triangular signal the output bidirectional so we cannot use it here. So we took a +4V Vdc reference voltage and a "Saw tooth" carrier wave tweaking the value of the vpulse property of "Pspice Schematics" and used the same circuit diagram of Figure: 2.1 to create a DC-DC Unipolar Converter.



| VPulse Properties | Value |
|---|---|
| V1 | 0 |
| V2 | 5 |
| TD | 0ms |
| TR | 19.9ms |
| TF | 0.01ms |
| PW | 0.001ms |
| PER | 20ms |

Figure 3.2.1: Saw tooth Unipolar DC-DC Converter

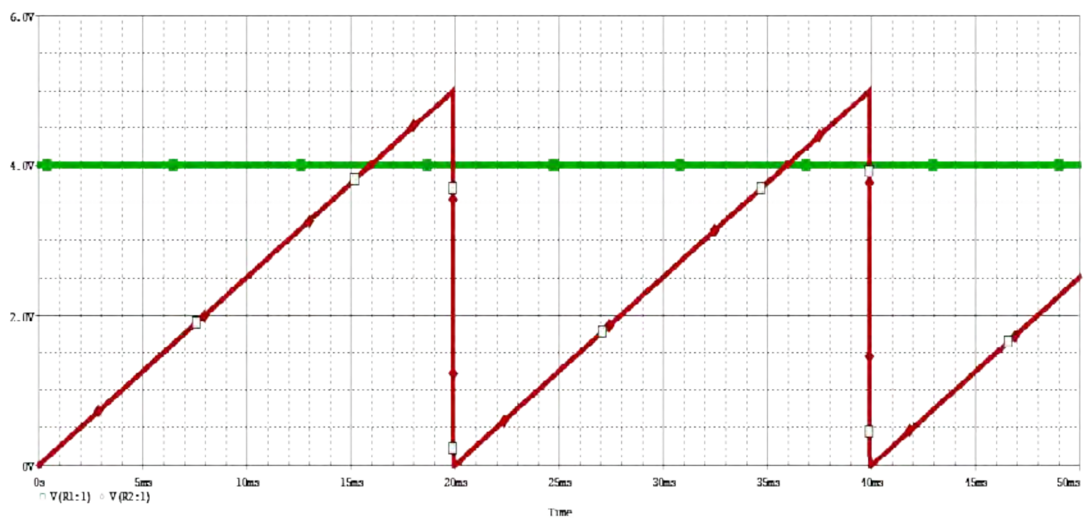



Figure 3.2.2: Input Signal to the Op-Amp

By increasing the rise time significantly more than the fall time we create the Saw tooth waveform.

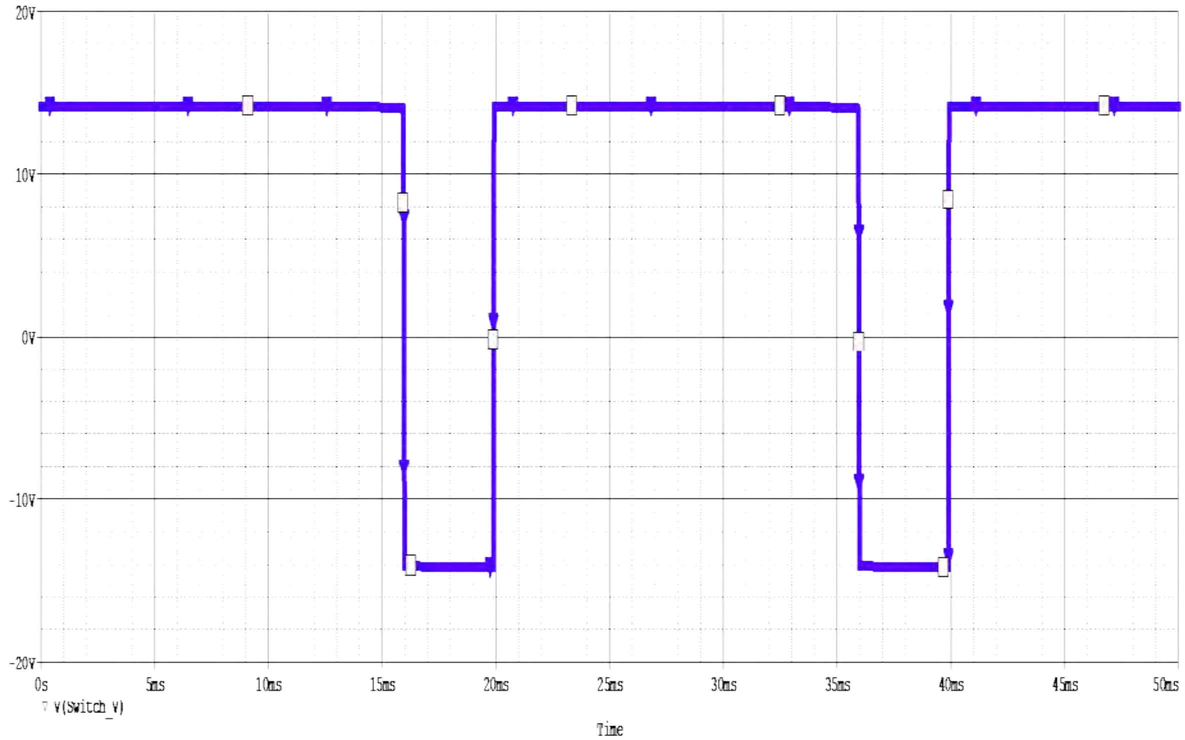



Figure 3.2.3: Switching Signal

After putting 200V DC Input and using the switching signal to operate the MOSFET we get an output of 185.214V (Figure 2.5.3)

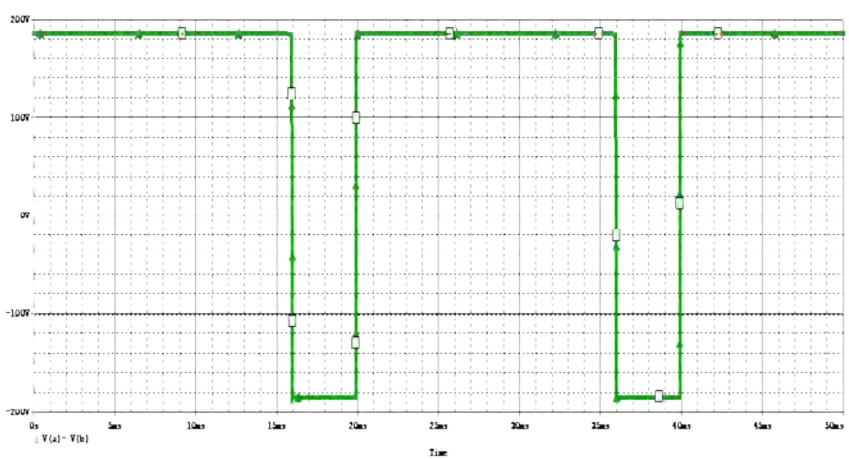


Figure 3.2.4: Output

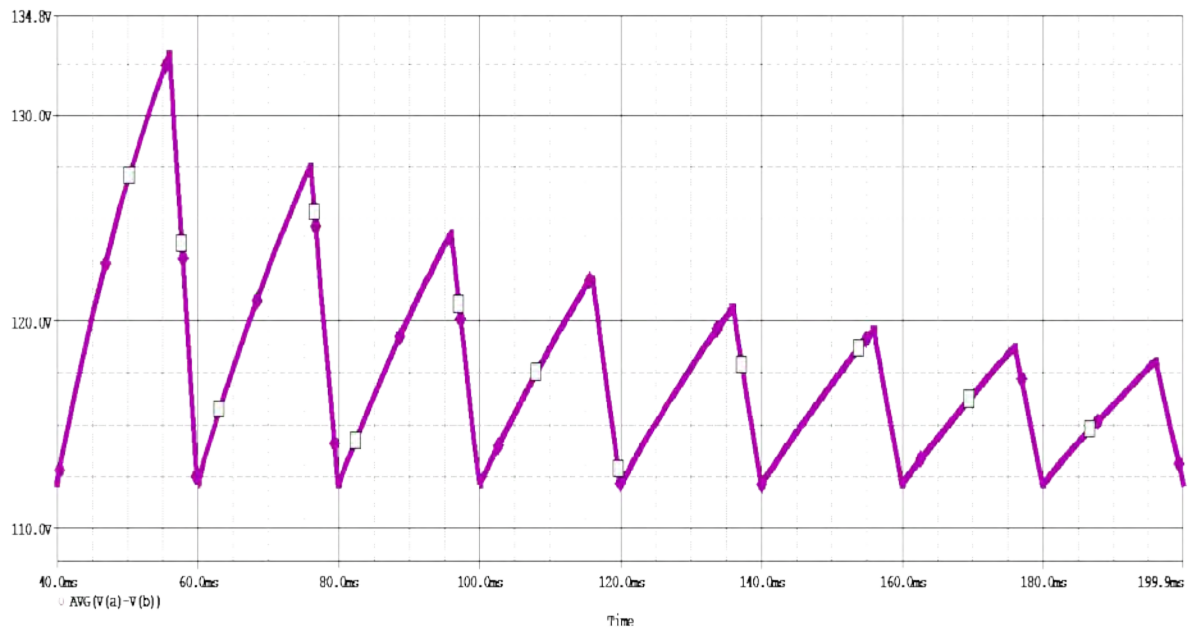



Figure 3.2.5: Average Voltage of the Output

After this simulation, we want to compare it with the same form of circuit having a lower reference voltage. In this case we are using +1V Vdc. Therefore, we get the following output and average voltages.

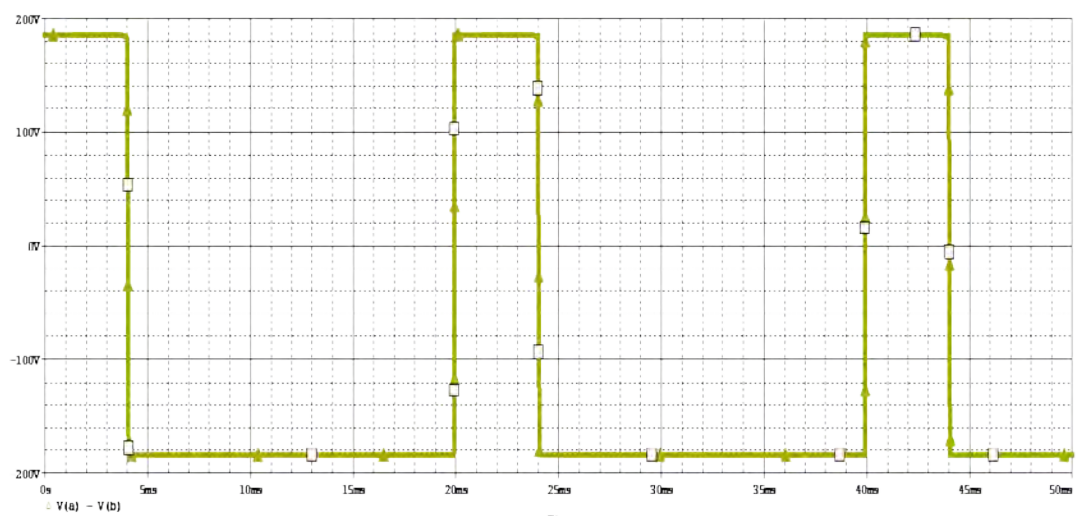



Figure 3.2.6: Output Voltage

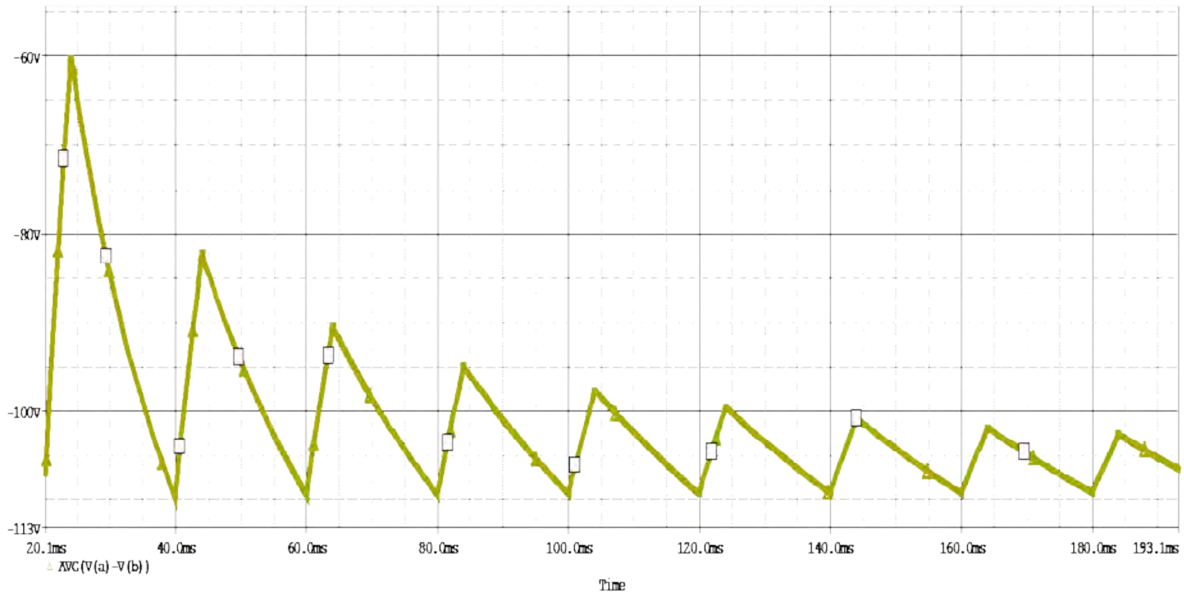



Figure 3.2.7: Average of Output Voltage

So from the Figure 2.5.3 up to Figure 2.6.2 , we see that the duty cycle of the output signal decreases significantly due to the changes made to the reference voltages from +4V to +1V. Accordingly, the average of the output goes from Positive value to the negative.

# Chapter 4

# Simulation of DC-AC Converter

### 4.1 Bipolar DC-AC Converter

Bipolar inverters give bi-directional outputs as it oscillates from positive to negative side. To generate an AC waveform from DC supply we used MOSFET switches like before and to control the switches we used sinusoidal wave as reference instead of the DC voltage and after that same circuit structure like Figure 2.1 can be used to create this inverter.

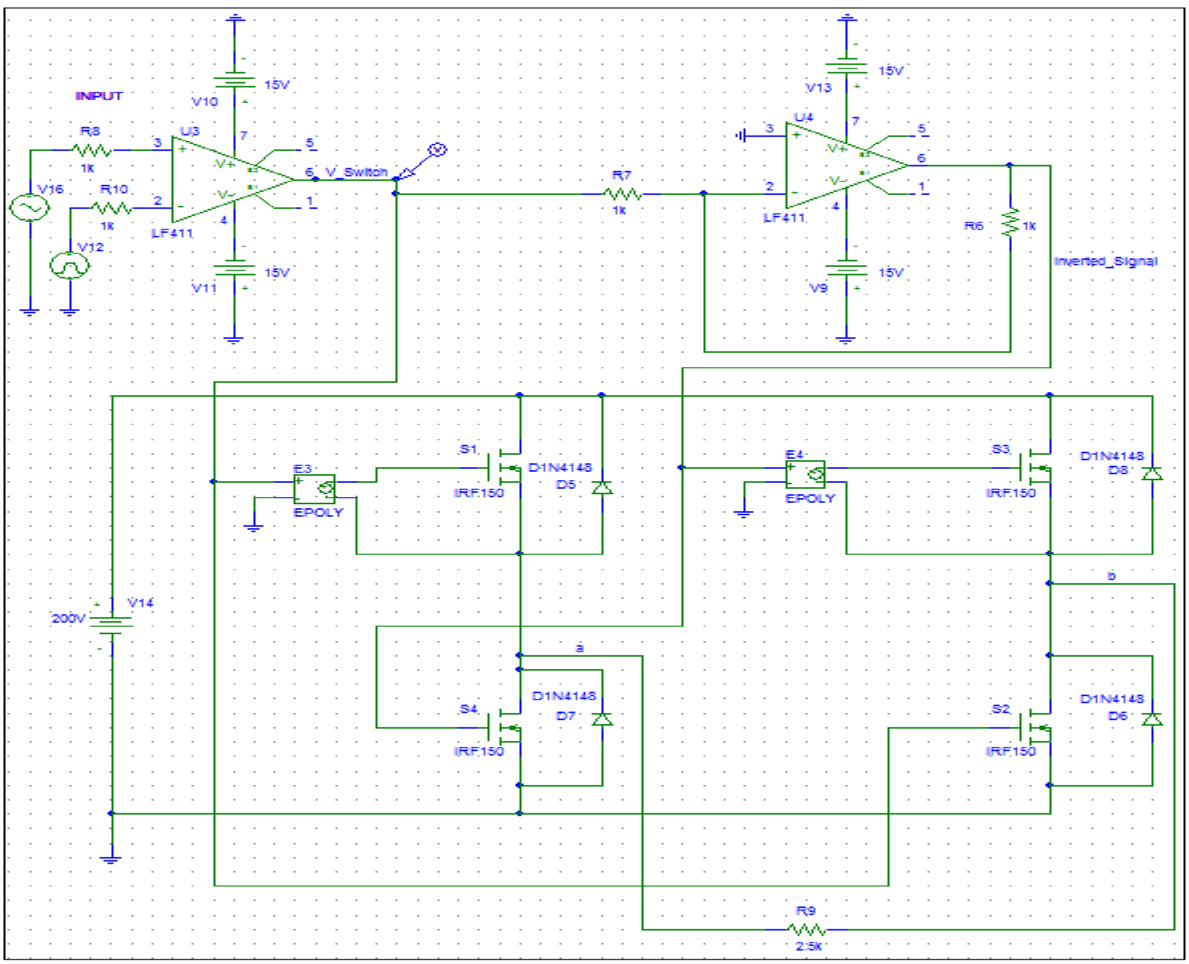



Figure 4.1.1: Bipolar DC-AC Converter Circuit Diagram

For implementation of this circuit we used two LF411 Op-Amp, four IRF150 MOSFET, four 1K & one 2.5K resistances. We used 200V DC supply to be converted into AC supply. We used the following Vsin properties to generate the sinusoidal signal.

| sin Properties | Values |
|---|---|
| VAMPL | 4V |
| FREQ | 50Hz |

Here we used a triangular wave as a carrier wave. To create this signal we had given the following inputs to Vpulse.

| Vpulse Properties | Value |
|---|---|
| V1 | -5V |
| V2 | 5V |
| TD | 0 |
| TR | 0.5ms |
| TF | 0.5ms |
| PW | 0.005ms |
| PER | 1ms |

**Control Circuit:**

We have four MOSFET switches S1, S2, S3 & S4. (S1 and S2) switches are on when $V_{sin}$ is greater than $V_{tri}$ . At the same time, the switching signals are inverted using an inverting amplifier and those negative values keeps the other (S3 & S4) turned off. When $V_{sin}$ is less than the $V_{tri}$ then the inverted switching signals turns the S3 & S4 Switches on. This is how a DC voltage is converted into AC supply in this circuit (Figure 2.7)

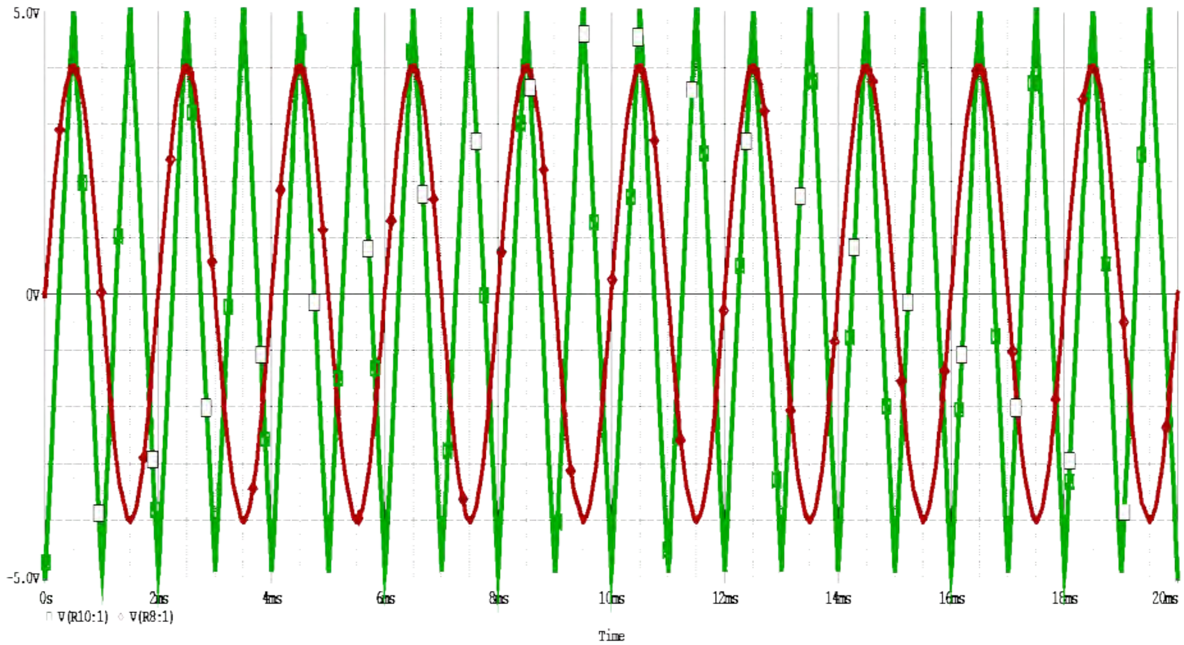



Figure 4.1.2: Input Signal

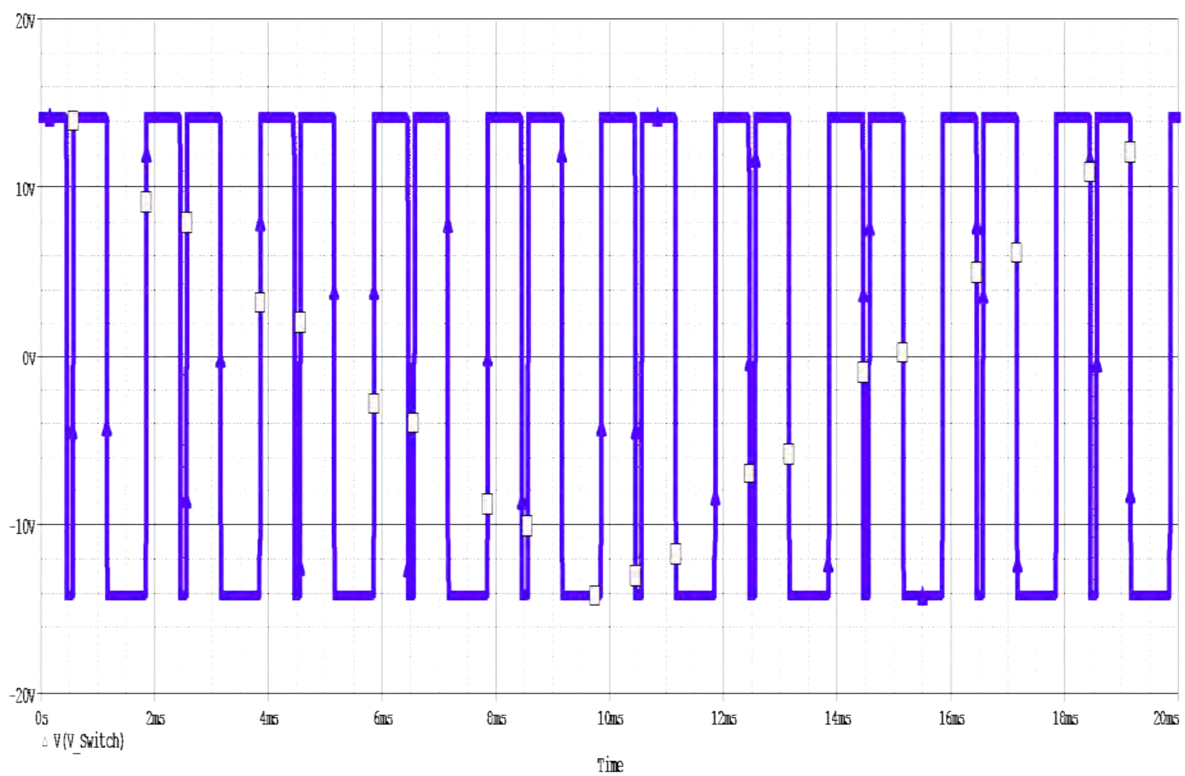



Figure 4.1.3: Switching Signal

As the switches work simultaneously, we get an output of 185.213V from a DC input of 200V

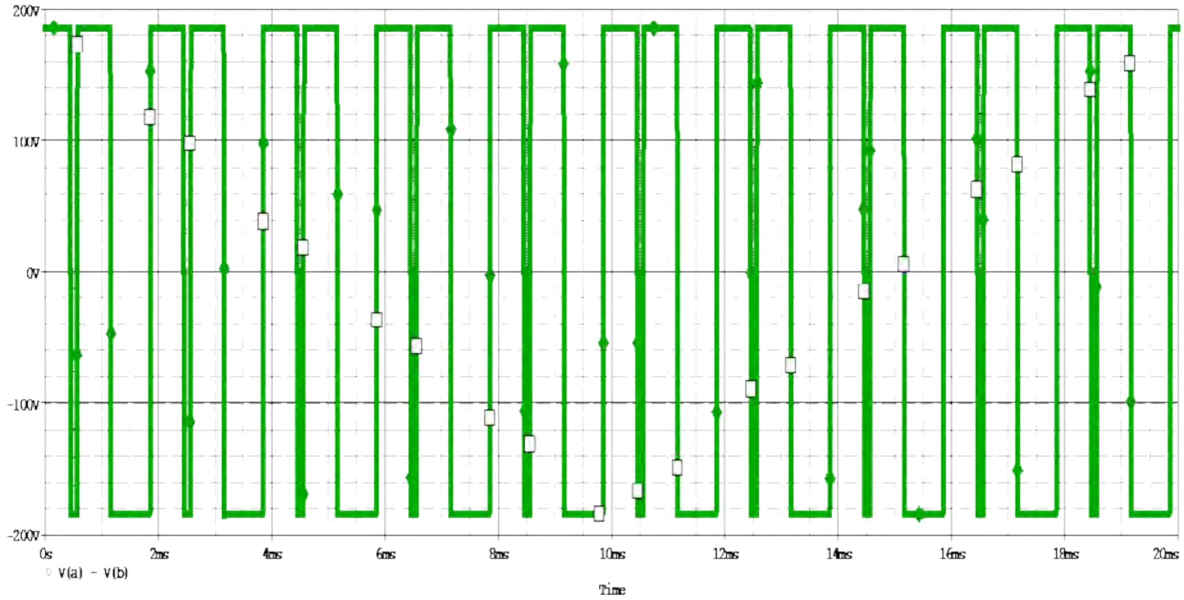



Figure 4.1.4: Output Voltage

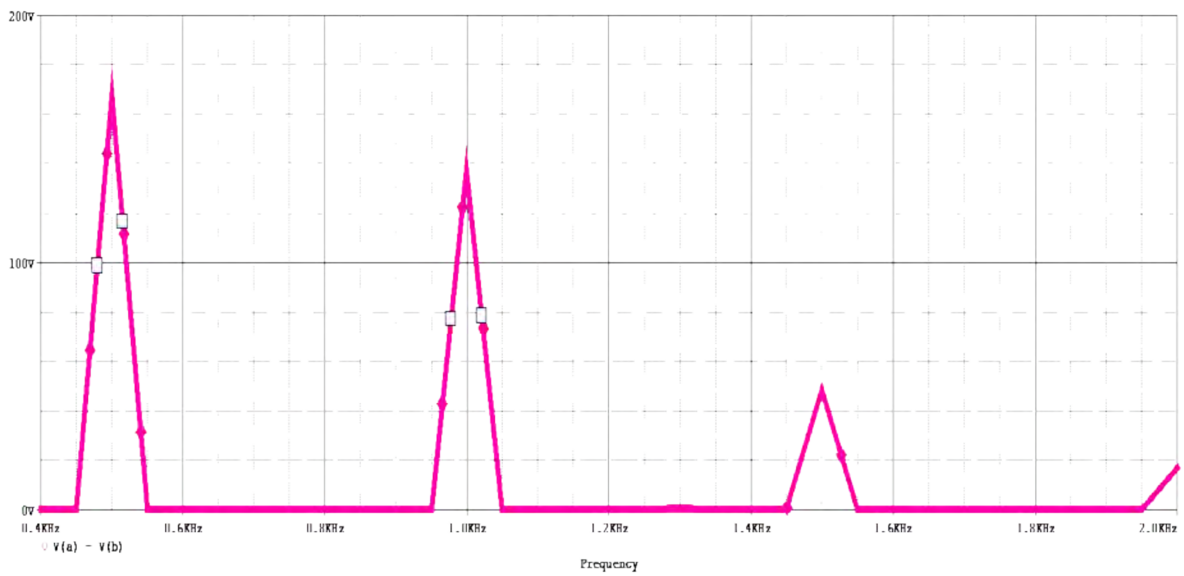



Figure 4.1.5: FFT Analysis of Bipolar DC-AC Converter

In case of Inverters, it is very important to remove the unnecessary harmonics to get a good output keeping only fundamentals because the fundamental frequency drive the load attached to it.

## 4.2 Bipolar DC-AC Converter with Filter

For eliminating the harmonics, we designed a low pass filter and added this with the circuit. Our goal is to get a better output wave shape and result. For determining the values of the components of the filter we used trial and error process.

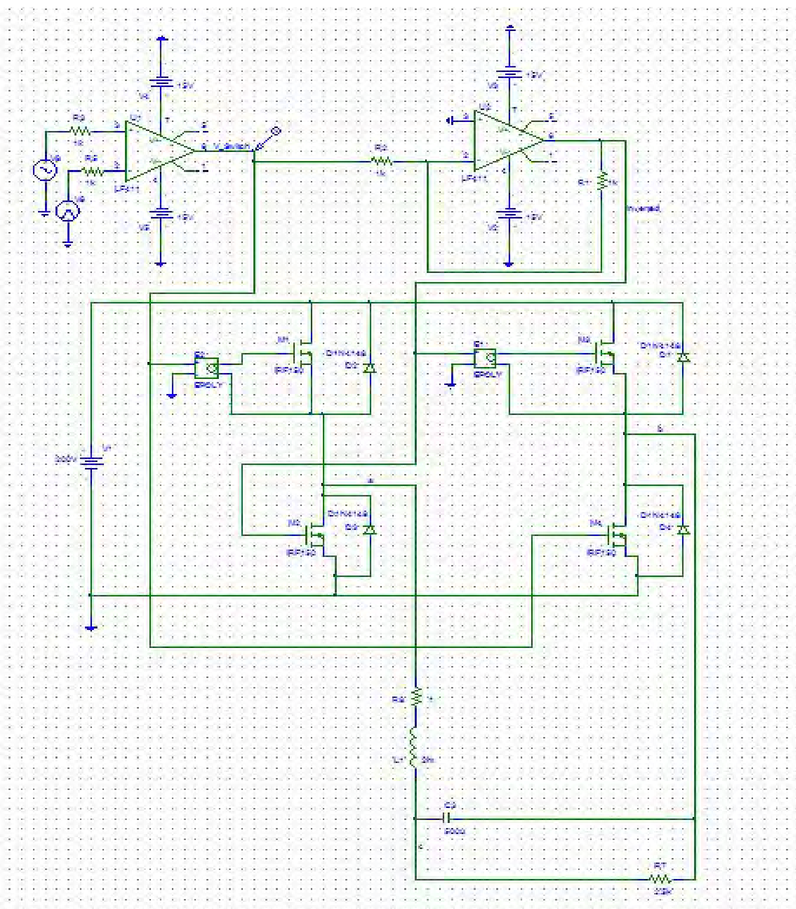


Figure 4.2.1: Bipolar DC-AC Converter with filter

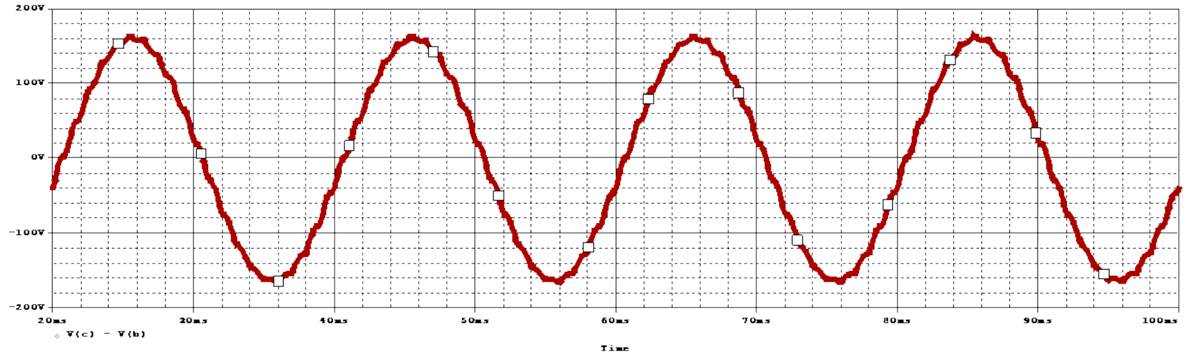



Figure 4.2.2: Bipolar DC-AC Converter output with filter

As we can see that, we are getting almost pure sinusoidal output because the filter only kept the lower frequency and eliminated rest of the harmonics. We can understand this better by the FFT analysis.

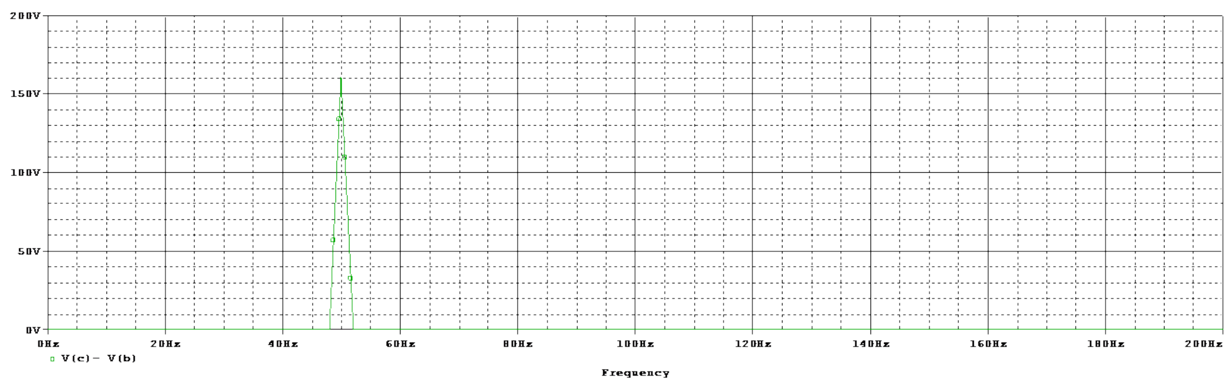



Figure 4.2.3: FFT Analysis

We can clearly see that the other harmonics are eliminated except for the lower frequency at 50Hz. For this reason, we get almost sinusoidal output as we desired.

### 4.3 Unipolar DC-AC Converter

Unipolar inverters switches between zero to $+V_d$ during positive half cycle and zero to $-V_d$ during negative half cycle. Therefore, to create this inverter we need two switching signals and their inverted signals to drive four MOSFET switches separately because unlike Bipolar inverter only two switches turns on at a time.

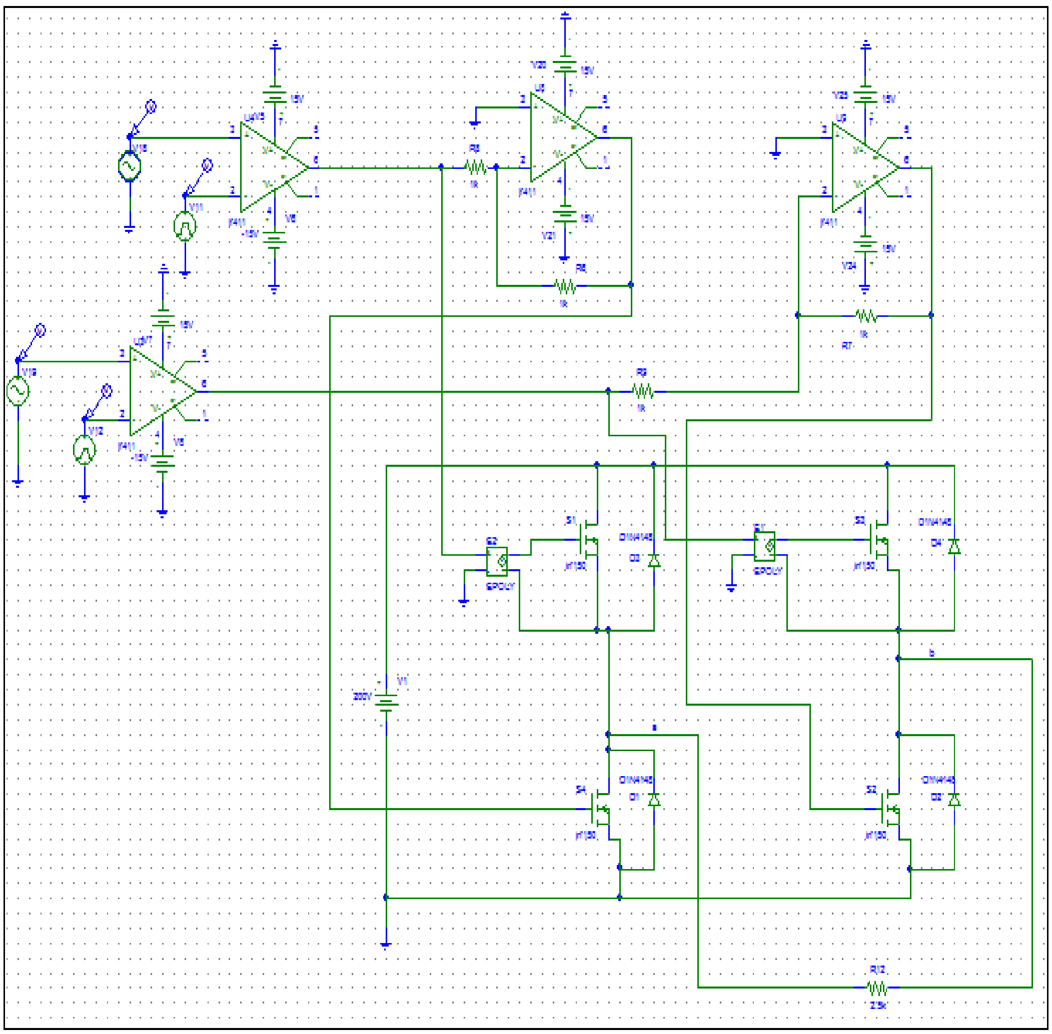


Figure 4.3.1: Unipolar DC-AC Converter Circuit Diagram

For implementation of this circuit we used four LF411 Op-Amp, four IRF150 MOSFET, two 1K & one 2.5K resistances. We used 200V DC supply to be converted into AC supply. We used two

$V_{sin}$ devices in the simulation to get the switching signal. Among these $V_{sin}$ one has a 180 degree phase shift to generate an input like the following –

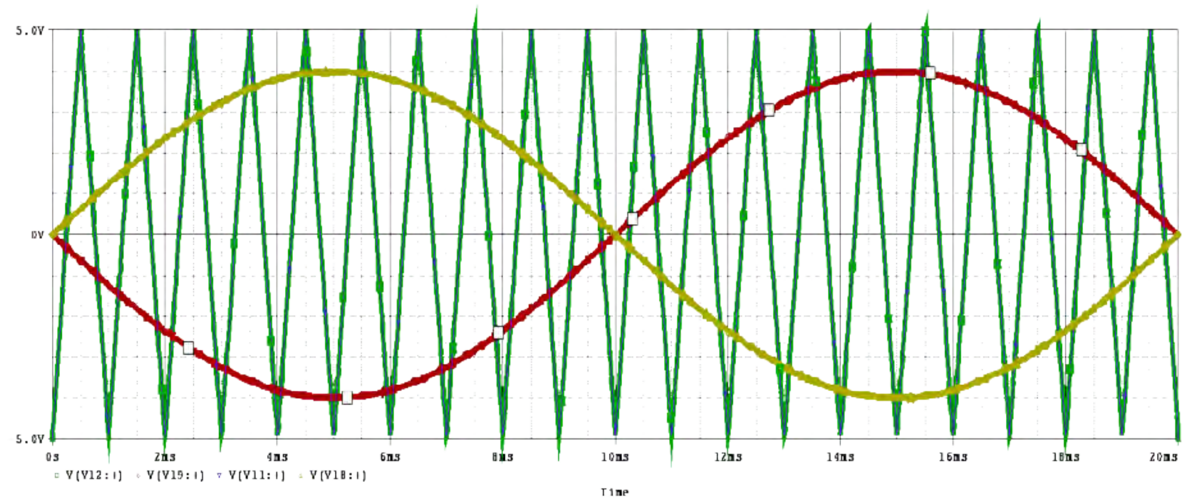



Figure 4.3.2: Input Signal

After generating the input signal, we now compare this signal using a LF411 Op-Amp to get our first switching signal.

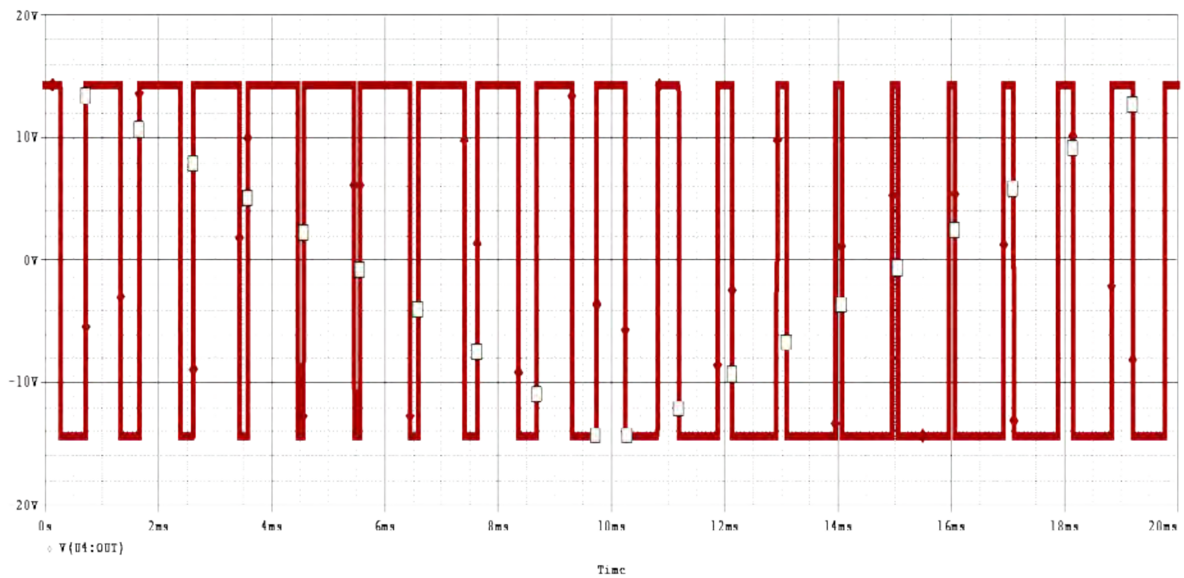



Figure 4.3.3: Switching Signal without phase shift

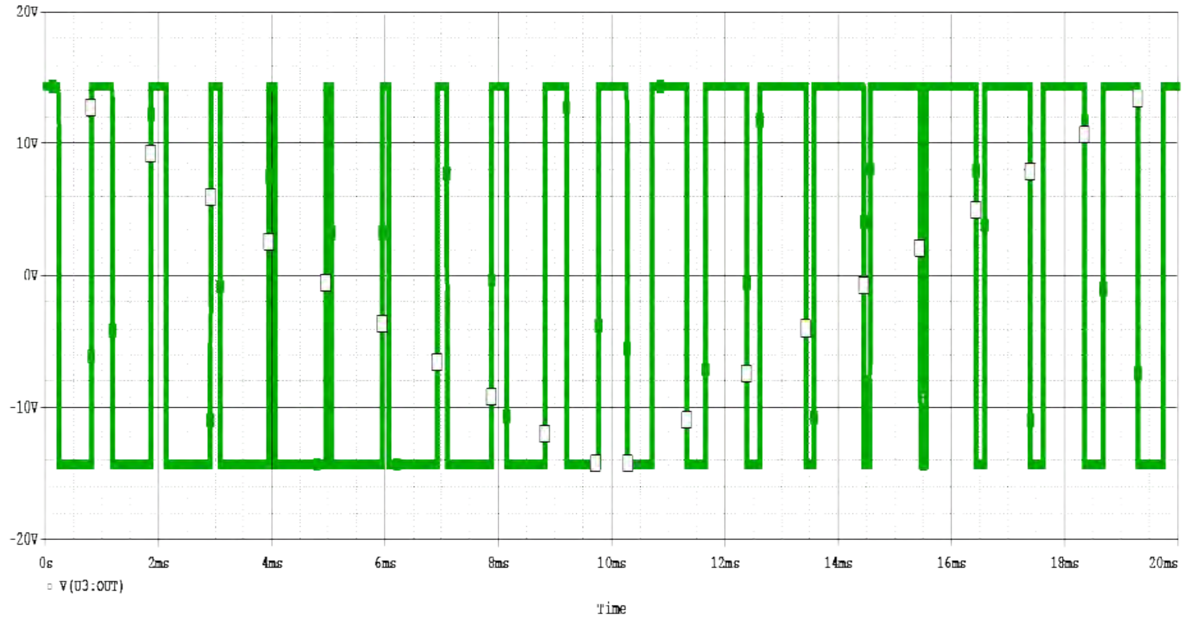



Figure 4.3.4: Switching Signal with 180 degree phase shift

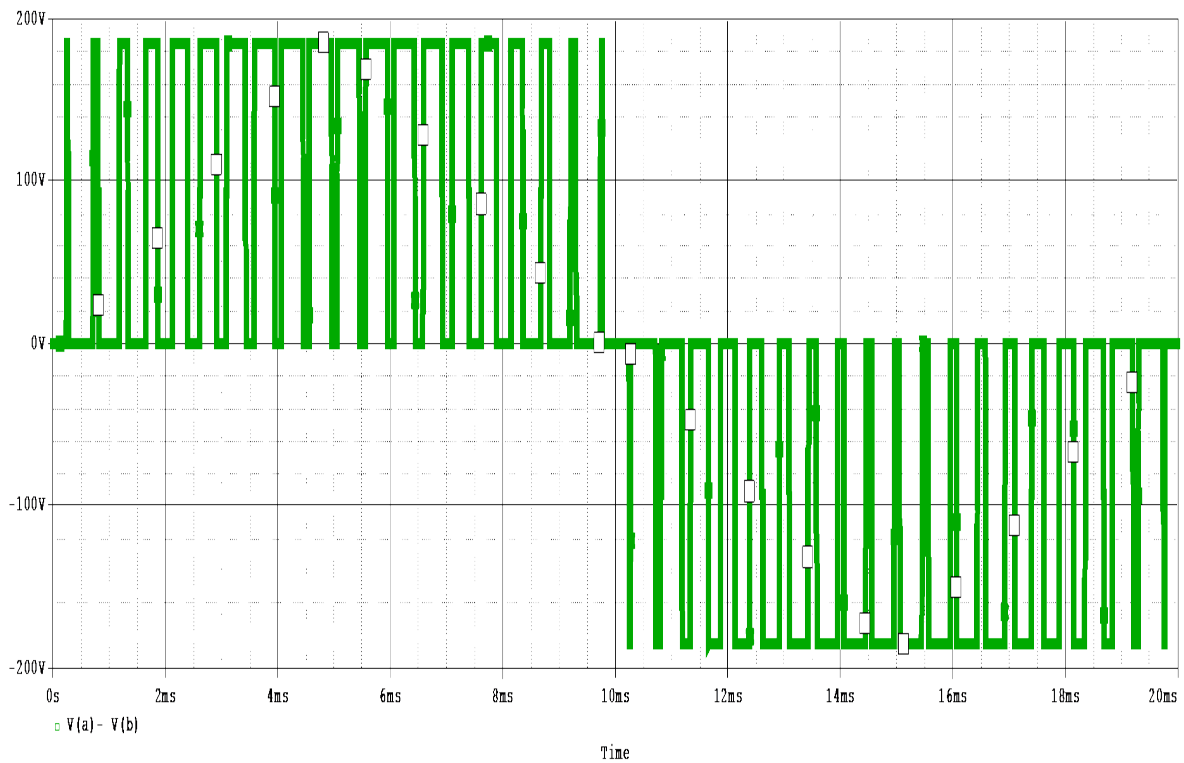



Figure 4.3.5: Output Voltage [V(a)-V(b)]

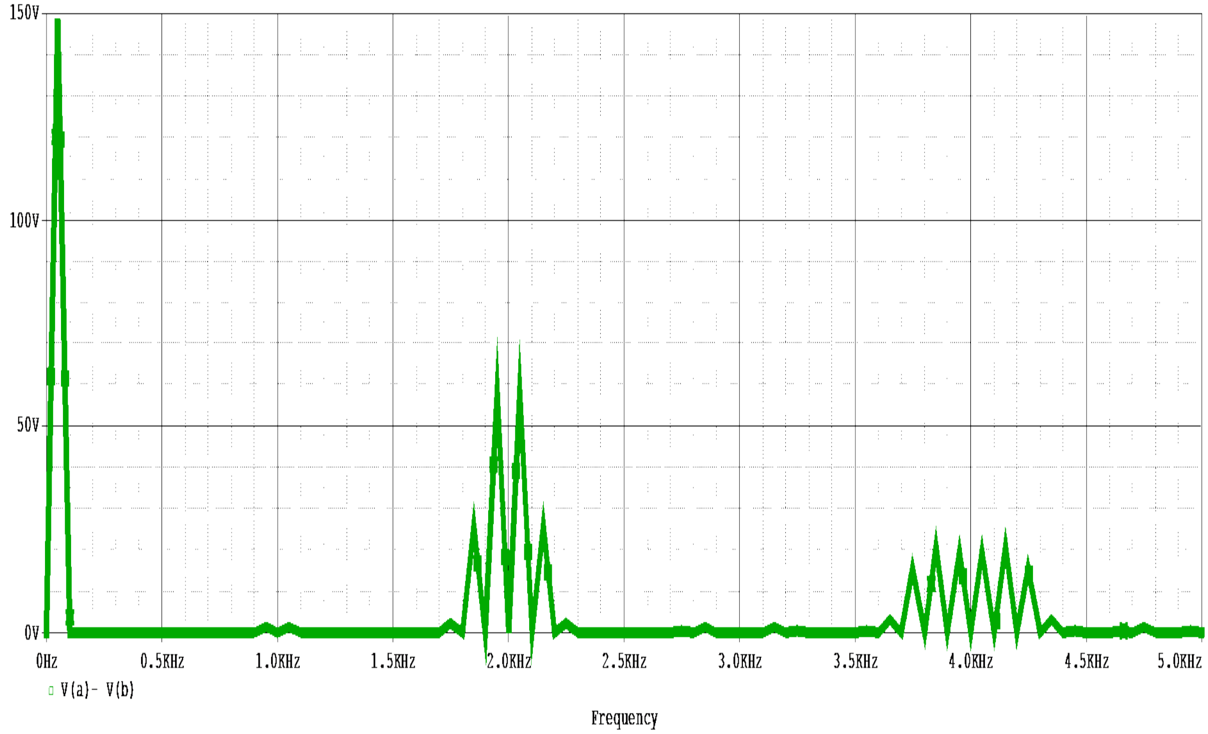



Figure 4.3.6: FFT Analysis of Unipolar DC-AC Converter

From the above Figure 2.8.5, we can see that we have our fundamental frequency between 0Hz to 250Hz. This is the harmonic part, which drive the load connected to the inverter. The rest of the harmonics can be eliminated using a filter, which give us a more smooth output curve to produce AC signal.

**4.4 Unipolar DC-AC Converter with Filter**

Here we will try to implement the same filter we used in the bipolar circuit and try to find out if there is any improvement in the output wave shape. The circuit diagram with the filter is given below.

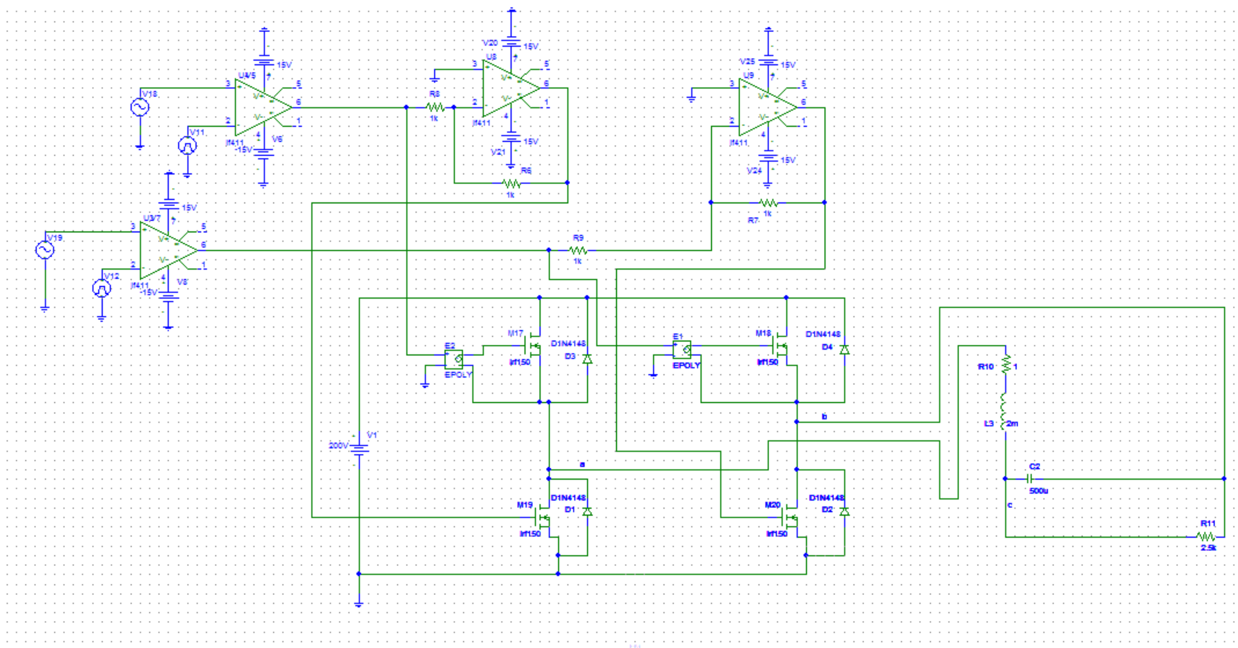


Figure 4.4.1: Unipolar DC-AC Converter with filter

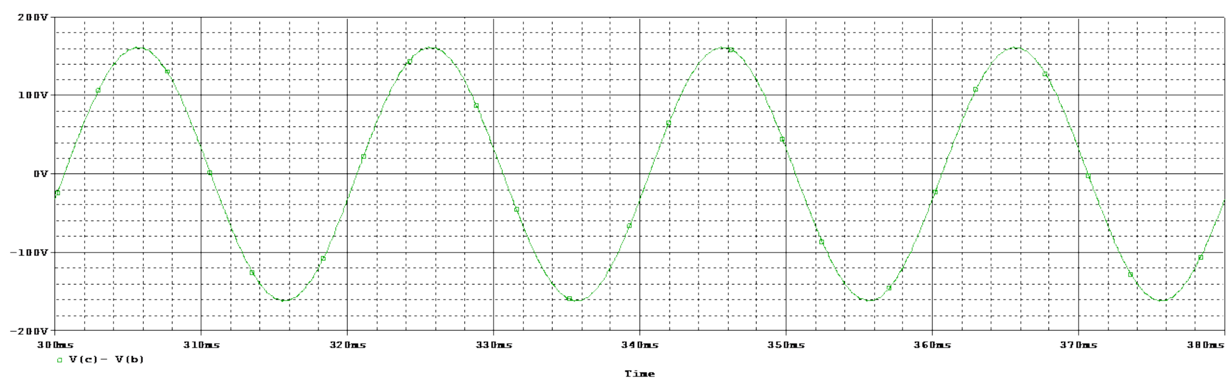



Figure 4.4.2: Output Wave Shape

We can see that in the output of the circuit we get a pure sinusoidal wave shape in the output. The curve is much smoother than the output of bipolar DC-AC converter. This is because of the filter that eliminates the unnecessary harmonics.

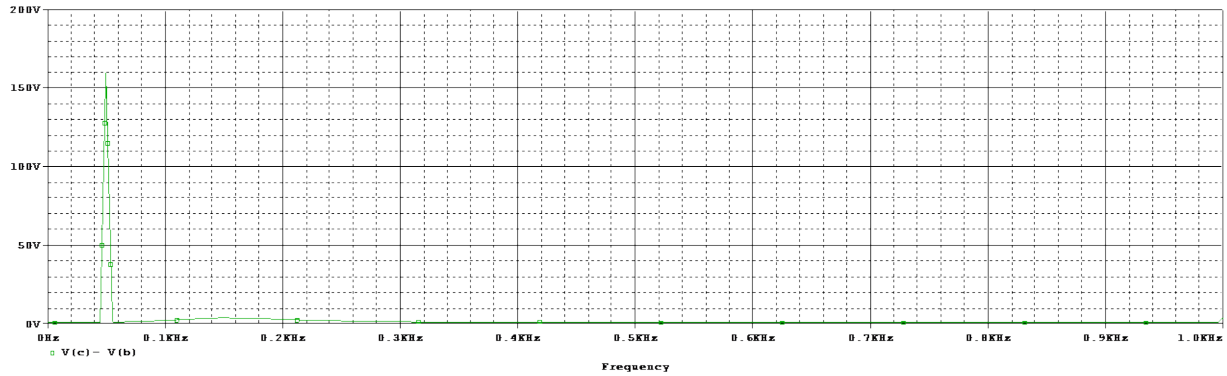



Figure 4.4.3: FFT Analysis

Using the FFT analysis, we can see that all the harmonics are eliminated except for the 50 Hz. In case of unipolar, the THD performance is better and filter requirement is less.

# Chapter 5

# Future Research and Conclusion

## 5.1 Future Research

As, we have used single-phase pulse width modulation inverter, we can improve further by applying it into three phase inverter, multilevel inverter .However, it will give us accuracy and good efficiency to get the desired output.

### 5.1.1 Three-Phase Inverter:

Normally, a basic three-phase inverter is consisted of three single-phase switch of inverter. With The help of that switches, three load terminals of three phase inverters are connected. Each switches are connected the three load terminals. Those three switches are the main controller of three-phase inverter. Usually, these three switches operate 60-degree point for the output waveform. Line to line output waveform is created for the operation of switches of three-phase inverter. However, that line-to-line waveform has six steps. As the output waveform, which has six-step, waveform has a step of zero-voltage. Moreover, this zero-voltage is occurred between the positive and negative sections. Overall, pulse width modulation techniques are applied to six-step waveforms so that the third harmonic and its multiples can be cancelled out. The main reasons to use three-phase inverter over single-phase inverter are that there are certain limitations in single-phase inverter. First, we cannot get constant power supply in single-phase inverter. On the other hand, we can get constant power, which is delivered by three-phase inverter. Therefore, we can use the three-phase inverter as an uninterrupted power supply circuit. For that reason, it will provide uninterrupted power to the critical load system. Moreover, the output and the efficiency is more accurate in three phase over single-phase inverter. However, three phase inverters are very cheap, smaller and have starting properties. On the other hand, single phase are not very cheap. As a result, it will be quite handy for anyone to get the three-phase inverter in a cheap price. Since, we get the good efficiency with the help of three-phase inverter; we can use it in the medical machines to get the correct output. Mostly, in undeveloped country, those medical machines are not maintained properly or the Government are not willing to give fund for those outdated machines where the patient does not get the proper treatment because of the wrong result of those machines. Therefore, we can use the three-phase inverter on those machines so that the patient get the proper result of their disease. Thus, they will get the proper treatment for their disease. As Bangladesh is a developing country, the Government is unable to fund more for the poor people of our country. Therefore, most of the poor people do not get the sufficient medical treatment and the price of those medical machines for the test is very high for them. Moreover, sometimes they get wrong treatment for the wrong result from the medical test. Nowadays, there has been planning inverters with three-phase pure sine output voltage, which is designed for railway applications. For the development country like Bangladesh, we can also try to improve our railway conditions by designing a three-phase output. Economically, it will be very helpful for a country like Bangladesh because it will cost very little money. However, it will be a low profile railway if we want to build it with the help of three-phase inverter but it will be very helpful for our country. Moreover, three-phase inverter is used in air conditioning system also. Because of the efficiency and low power all the electronics companies are opting to use three phase inverter which helps the buyer to buy it in reasonable price. Usually, it will also ensure them a good service and the three phase inverter will keep the power low. Therefore, the electric bill will be lesser than the before when people use air conditioner without three phase inverter. In today's life, people are opting to buy an electric car, which is powered by an electric motor. In previous time, a gasoline engine powers electric car. However, electric motor gets the energy from a controller. Electric car normally uses its energy, which is stored in its rechargeable batteries. Normally, those batteries are recharged with the household electricity. We know that nowadays the EV (electric vehicle) batteries are used for recharging which is three-phase inverter. Moreover, this three-phase inverter helps the batteries to recharge faster of electric vehicles. Besides that, the three-phase frequency inverter is used for the control of speed of vehicles. In Bangladesh, most highway buses drives very recklessly. So, with the help of the frequency three-phase inverter, the speed of those transports can be controlled. Mostly, we can see that nowadays all the electronics materials are made with the help of three phase inverter. However, the use of single-phase inverter is decreasing day by day. Therefore, we need to know the proper use of three-phase inverter so that we can implement that inverter properly. Furthermore, there is also further studies regarding three-phase inverter. However, we need to get the correct information regarding three-phase inverter. Nowadays, three-phase inverter is also used in power grid for high efficiency. Moreover, three-phase inverter will help to increase the high power in power grid without any drawbacks. Because of that reason, most of the countries are now opted to use the three-phase inverter in power grid. By using the three-phase inverter in power grid, the efficiency will be high. That is why, all the countries prefer to use the three-phase power grid inverter.

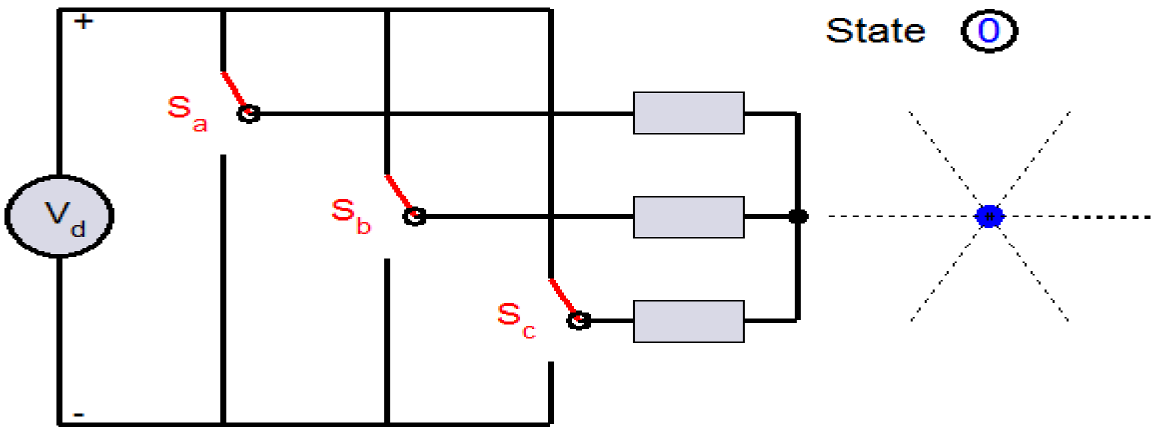



Figure 5.1.1: Three phase inverter

### 5.1.2 Multilevel Inverter:

Multilevel inverter is an inverter, which is a power electronics device. Multiple inverter is capable of providing desired alternative voltage. This desired alternative voltage is occurred in output. However, to get the desired alternative voltage, multiple lower level Dc voltages are used as an input. Mostly, two-level inverters are used to generate from AC voltage to DC voltage. There are many advantages to use the multilevel inverter. It has the ability to generate output voltages but there will be a very low distortion. Therefore, multilevel inverter helps to decrease the level of distortion very low. Moreover, it will lower the dv/dt. For that reason, the output will be accurate and efficient. On the other hand, they draw the input of the current that is a very low distortion. So, it is very helpful to get the low distortion and the output we get is very efficient. Besides that, the multilevel inverter also generates a smaller common mode voltage. The smaller common mode voltage will help the inverter to get the desired voltage it needs for the work. On the other hand, the multilevel inverter can operate a frequency with the help of a switch that is very low.

The types of multilevel inverters are given below:

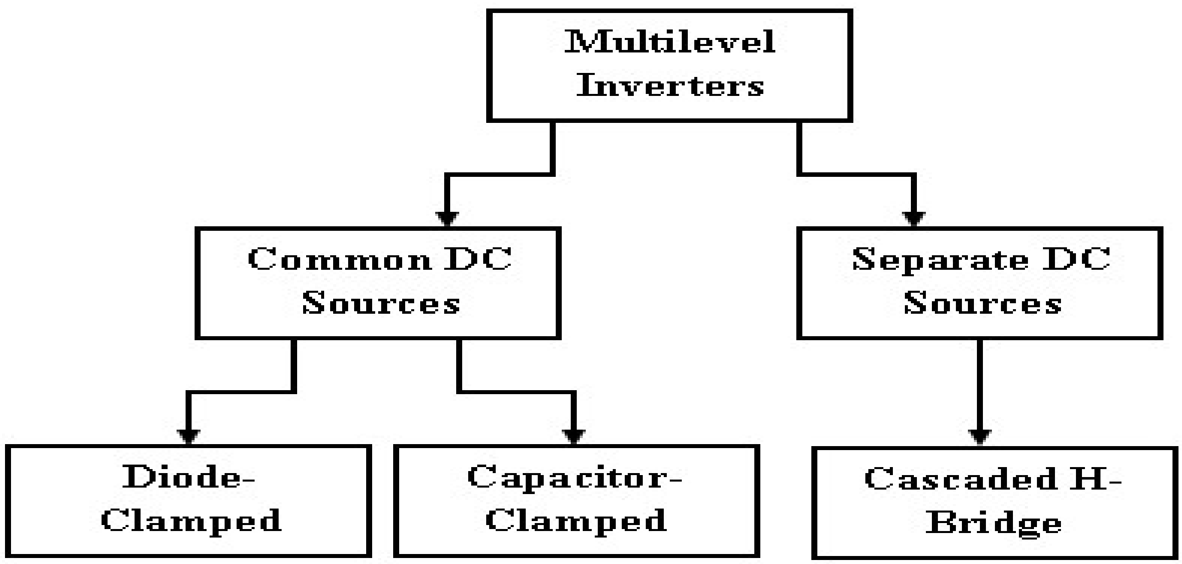



Figure 5.1.2: Multilevel inverter topologies

Therefore, the multilevel inverters are becoming popular day by day for its high power in electric over the years. Moreover, the less disturbances and the function of a lower switching frequencies are the main advantages of multilevel inverter than the ordinary two-level inverters. So, multilevel inverter is now used in high power area because of its efficiency and minimum switching frequency. Nowadays, multilevel inverter is used in power grid because of its minimum switching frequency. The developed countries like United States America, Australia, Canada and England are using multilevel inverter in power grid to get the better output and efficiency. The multilevel inverter does not need maximum switching frequency. Therefore, there will be less fault gotten from the output of the multilevel inverter. Those developed countries are opted to use it because of its efficiency and accuracy. Most of all, it has become more popular because of its better result. Besides that, multilevel inverter is now used as an input of a solar energy, which will give the maximum accurate output for using it. Moreover, the solar energy needs energy to operate properly. Thus, the multilevel inverter is used in solar energy to store the energy quickly and function properly. As we know, active filters are now used in many electronics devices such as in the music industry, in the playback or record etc. So, the multilevel inverter is used in active filters for the good function and better effective for them. Normally, active filters are the filters, which are used in communication system and to put the end of the noises, are their main priorities. Moreover, multilevel inverter helps the active filter to suppress the noise effectively and get the better result with the help of it. Industrial motor drives are also used with the help of multilevel inverter for its quality and better result. Nowadays, there is a lot of competition in the industries. So , industries tries a lot to get the best motor engine with a reasonable and give their users a better product so that they can get the appreciation and do good in the competitive business market. However, the multilevel inverter gives a better efficiency and high quality. So, the industries are opting to use the multilevel inverter for their motor drives. Besides that, the multilevel inverter is used in transportation also. As, it is reliable and better inverter among inverters so the industries are using it more in transportation. However, we can see a better quality cars, buses, truck on the roads that are made with the help of multilevel inverter. Besides that, the transportation quality is becoming high and the demand of transport is becoming high. Therefore, the industries are in competitive world where they has to ensure that they provide a better engine and quality transport that their customer can get.  That is the main motto of those industries to hold their real customer. Therefore, the multilevel inverter have developed to a well-established technology. Moreover, it has become a smart solution for many other technologies.

Now in present, multilevel inverter is becoming an attractive solution for high-power application. So, the multilevel inverts are mostly used in everywhere in high-power applications. Moreover, the power of the quality can be developed with the help of that inverter. It is really effective for medium-voltage and high-power. Moreover, the multilevel inverter is very useful for the minimum switching frequency. Although, there is another inverter, which is the classical two level converters, there is a tough competition between the multilevel inverter and the classical two level inverter. Though, there also needs some improvement for multilevel inverter, therefore, the researchers are trying their best to improve it.

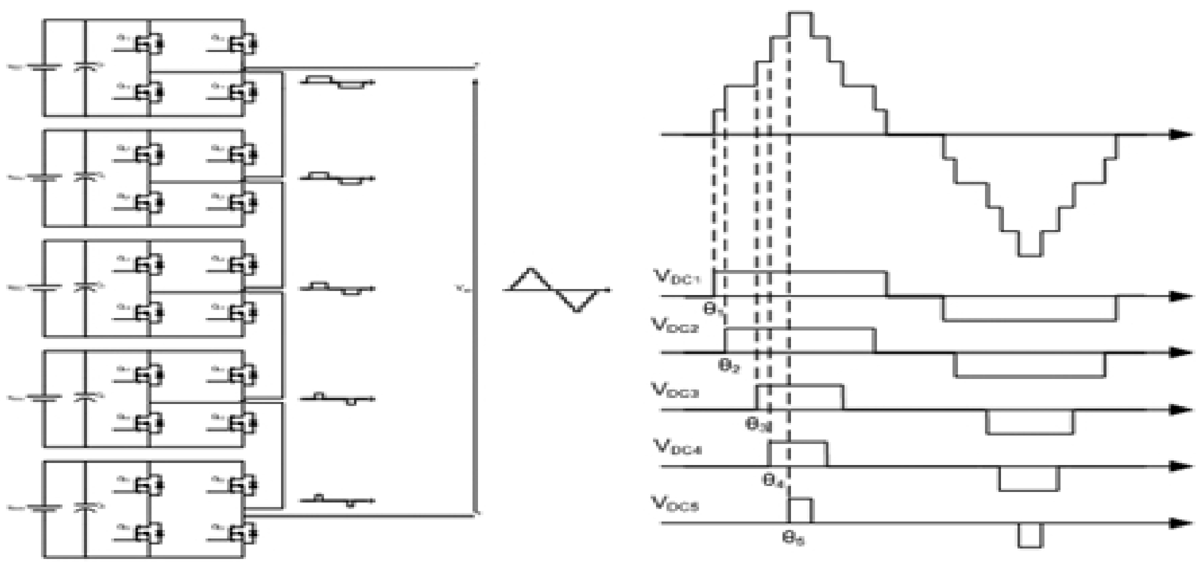



Figure 5.1.3: Multi-level Inverter Circuit

**5.2 Conclusion:**

Converters are electrical circuits, which usually converts a voltage level to another. Inverter is also used for different purposes. DC-DC converters are important in devices especially in portable device such as mobile phones and laptops. PWM inverters are one of the most used power-electronics circuits in practical life. These inverters are capable of producing ac voltages of variable magnitude as well as variable frequency. PWM inverters can be used as single phase as well as three types. Most of the inverters use PWM technology to produce AC output from DC input or DC from DC input. The inverters constructed based on this Pulse Width Modulation technique are superior in most aspects than other inverters designed using the normal conventional design. The PWM based inverters and converters generally uses MOSFET switches in the control circuits to produce output. On the other hand, converters are generally converts on power to another power with help of varying the frequency and voltage. There are four types of converter, which are AC to DC converter, DC-to-DC converter AC-to-AC converter, DC to AC converter.

However, Inverter is an inverter that transform DC voltage to AC voltage. There are three types of inverters, which are pure sine wave, modified sine wave and square wave inverter. Pulse Width Modulation (PWM) is a technique through which the total harmonic distortion (THD) of load current can be reduced. After using some filter, the total harmonic distortion of the PWM inverter output will reduce significantly meeting the requirements. Bipolar inverters works from peak to peak. Simultaneously both positive and negative pulses can be generated from the circuit. Unipolar modulation needs two sinusoidal modulation waves with identical frequency and magnitude and 180º phase shift. The two sinusoidal signals are compared with same triangular wave [1]. The inverter output voltage does not switches simultaneously. There is a simulation of DC to DC PWM Converter, DC to AC PWM converter. However, all of those simulations are done with single-phase inverter, which has some limitation. Therefore, there is a plan for future research to overcome those problems and improve the output of simulation. To improve further we will apply three phase inverter, multilevel inverter .However, it will give us accuracy and good efficiency to get the desired output.

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