Study of
AC to DC Converter

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

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<u>Declaration</u>

We do hereby declare that the thesis titled "Study of AC-DC 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. Contents of work found by other researchers are mentioned by reference.

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<u>ABSTRACT</u>

The modern electronic devices operate with low DC output voltage. The AC utility supply needs to be converted and step down to a suitable DC voltage. During earlier days, the converters were huge in size and were expensive too. A remarkable reduction in size and price was possible due to the invention of switch mode power supply. This goal by expanding the power density which is achievable by decreasing the size of the passive/energy storage components such as the inductors, capacitors and the transformer. For better utilization of the existing electric energy the entire power system should be operated at high efficiency for that reason now a days we use different types of converter. In this thesis, study of the AC-DC converters are carried out along with relevant simulations to realize the deeper understanding on the topic Therefore, the main objective of this research is to study in detailed the working principles and applications of linear power supply in ac to dc converter.

Table of content

Chapter 04: Simulation and Result………………………..35

Chapter 05:

Conclusion & Future Work………………………………….40

Reference………………………………………………….41

List of Figure

List of Table

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Chapter- 01

Introduction

1.1 Introduction

At present time there is an increasing demand for efficient systems every time we communicate approximately electricity consumptions and so as to keep up with those needs engineers were coming forward growing efficient conversion strategies and additionally been capable of design circuits with excessive performance. Nevertheless, technology on this discipline remains improving with facing new demanding situations. Converter in power electronics converts power from one type to another by means of various the voltage or frequency. Power conversion is based on kind of the input and output power. Converter driven programs are broadly used. The electrical power conversion is an exceptional field of electrical engineering. The Power electronics is the utilization of solid-state gadgets to control of electric power and transformation of electric power. It is also restrictive as it excludes rotating machines (electrical motor and generator).Converter may do one or more functions and give an output that varies from the input. The converters are used to increase or decrease the magnitude of the input voltage, invert polarity or produce several output voltages of either the same polarity with the input, different polarity, or mixed polarities. The converters are used in nonlinear components. For example, the semiconductor switches, and linear reactive components. There are different types of linear components such as the inductors, transformers and capacitors for intermediate energy storage as well as current and voltage filtering. The size, weight and cost of the converter are mainly determined by these components. However, power conversion systems can be classified according to whether the input and output are alternating current (AC) or direct current (DC). Alternative current (AC) to Direct current (DC) is one of those heavily used conversion in power electronics system. For instance, a laptop battery adapter is the example of the AC to DC conversion. Here, adapter's input current is AC and output current is DC. The reason behind for using the constant DC voltage is that it is free of ripples or unwanted frequencies. The DC circuit is formed in such a way that the rectification and filtering process will be carried out properly. If the supply of DC voltage is not constant, a laptop cannot be charged properly. The main feature of the rectifier is it must handle the output current (load). After that, we connect the output of rectifier to the filter. As we know, filter

is nothing but a device, which filters out the ripples in the unidirectional ac voltage and converts it back to pure dc voltage. There are two kinds of filter used in the circuit, inductor and capacitor. Capacitors are the widely used filters. But instead of giving less value if we increase the value of capacitor some circuit we can get voltage greater than or equal to the dc output voltage (that must be same of transformer output voltage) so that you'll get a pure dc output without any ripples. Theoretically, it is recommend to use a high voltage capacitor (like 150% of output voltage) to get less ripple and a smooth graph. We try to add a couple of capacitors to get our desired output dc voltage lesser than the transformer output voltage, that is why we will connect a voltage regulator next to the capacitor. We are using 230V/50Hz AC supply which connect to step-down transformer which will step down and give a DC voltage depending on transformer rating that connect rectifier circuit ,which converts from AC to pulsating DC after that connect Capacitor (filter). Afterwards it converts pulsating AC to pure DC. In order to get constant DC we need to connect regulator IC - LM7805 that maintains the output voltage at a constant value. We are using LM7805 IC, which provides +5 volts regulated power supply. In the paper, we are going to discuss about the linear AC to DC Converter and try to build up the circuit with help of PSPICE software so that we can get the output and input shape of different type of rectifier. In addition, we try to collect the different changing value for changing the AC voltage and will try to simulate the output waveform. For this purpose, we will use PROTEUS software to get our desired result and waveform.

1.2 Motivation

Today is the universe of advancement and people are finding various sorts of things every so often. Power is a helpful type of vitality that can be diverted, just controlled and conveyed to a wide assortment of circulated topographically scattered consumers.AC-DC converter has wide variety of uses. AC signals cannot be stored and DC power or signals can be stored. In this way, to store the electrical we have to change over it into DC. Similarly, Digital contraptions require unfaltering voltages, thusly to get those steady voltage levels (DC levels) we need to change over AC into DC using rectifiers. AC can be transported over long separations as a result of its frequency and DC can't be transported as DC has zero frequency. Thus we have AC control provided in homes, industries. For testing, watching any electronic device or system we require dc supply. It is more successful to change over AC to DC. Since to change over AC to DC a little rectifier is adequate yet to change over DC to AC a convoluted inverter is required.

1.3 Background   Study

With not very many exemptions, conveyance of electric power is in AC system. With the headway of alternating to direct current converters are getting a recognized and commonly followed applications. Accordingly, ac dc converter has framed a functioning territory of research in recent times. The requirement for DC power may be supplementary, for example, use in electronic controls, or crucial, for example, the DC connection of a motor. In the meantime controlling bodies are upholding strict harmonics directions, for example, IEC 1000, Std 500 and so on. This is because of the powerful factor and low line current harmonics distortion prerequisites.

To change line frequency from ac to dc, a line frequency diode bridge rectifier is utilized. A large filter capacitor is utilized at the rectifier output to diminish the ripple in the output voltage. In any case, current drawn by this converter is peaky by characteristics for the larger capacitor. This input current is high in low order harmonics and because of the existence of these harmonics, the aggregate harmonic distortion is high and the input control factor is denied. Issues related with these low power factors also, harmonics, utilities will authorize harmonic standards and rules which will constrain the measure of current distortion permitted into the utility. It is greatly required to accomplishing rectification at near utility power factor and low input current distortion.

Chapter-02

Study of AC to DC Converter

AC-DC converters are electrical circuits that transform alternating current (AC) input into direct current (DC) output. They are used in power electronic applications where the power input a 50Hz or 60Hz sine-wave AC voltage that requires power conversion for a DC output. We utilize control electronic converters in our day by day life at home, business work places or in a mechanical situation. Converters have become an integrated part of industrial electric drives, power supplies and other automobile equipment's due to high power handling capability with higher efficiency. Power electronic components such as, Silicon Controlled Rectifiers (SCRs) [or Thyristor], Triode for Alternating Current (TRIACs), Insulated Gate Bi-polar Transistor (IGBT) are used for power electronic converters to control and change over electric power. The principle point of the converter is to deliver molding power regarding a specific application.
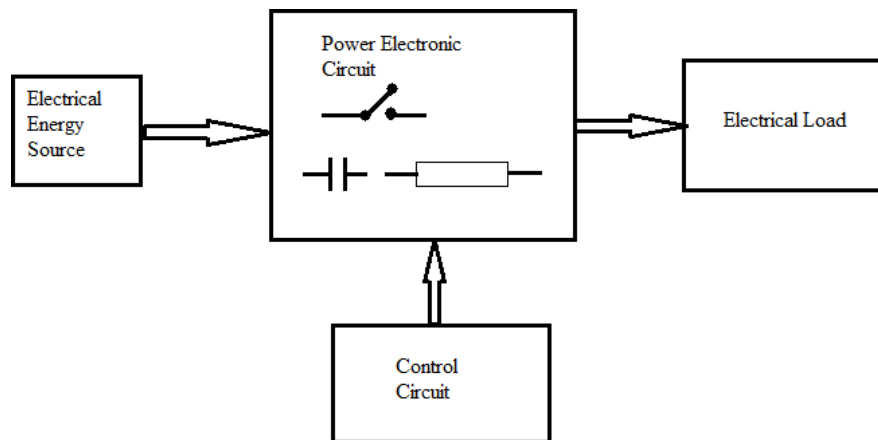
Fig 2.1: Block diagram of a power electronic converter.

The block diagram of a power electronic converter shows that it contains an electrical energy source, power electronic circuit, a control circuit and a load circuit. This converter changes one form of electrical energy to another.

Commercially available voltages are time varying voltages used in large quantities. Alternating current (AC) is the electric current which periodically reverses the flow of direction. Commercially a variable AC wave forms are Sinusoidal, Square wave, Complex wave form and Triangular wave.
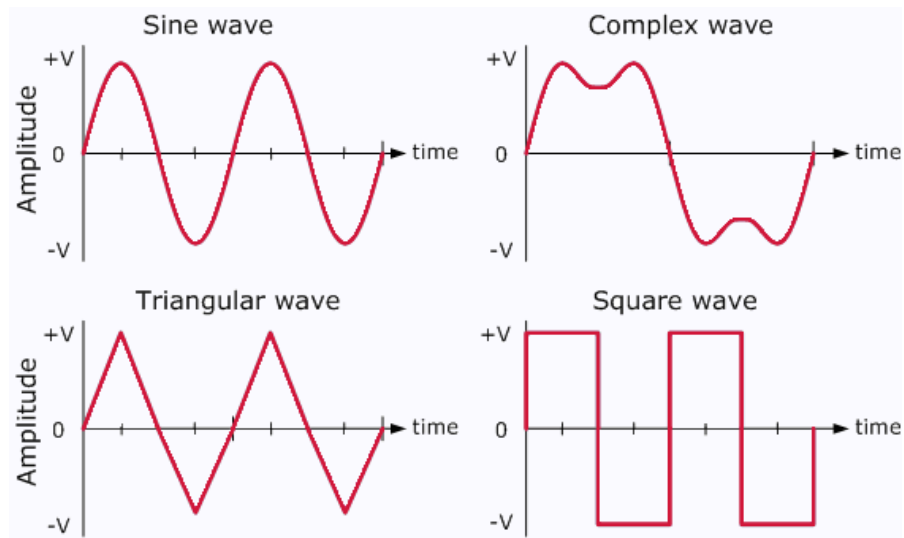
Fig 2.2: Alternating waveforms.

Our interest is in Sinusoidal ac voltage because this type of wave form is encountered and used throughout the world.

Conversion of AC current to DC current also refers to rectification process.

We are using AC current in our home but we cannot always use AC supply everywhere. Sometimes we need to convert this to DC source. That's why rectification process is necessary. AC to DC converter is generally called rectifier. The circuit rectifies the AC signal into a DC one by making the signal flow through only one direction. The output is further made smoother through filters.

Some examples of AC-DC converters are:

1) AC/DC converters (off-line) 3ph-Input/3KW
2) AC/DC converter (off-line) as insert unit
3) AC/DC converters (off-line) with 3 outputs, pen frame
4) AC/DC converters (off-line) as Build-In- Unit 6HE
5) AC/DC converters (rectifier) for Telecom Application

2.1 Basic Principle

The block diagram of a basic AC-DC converter is given below.
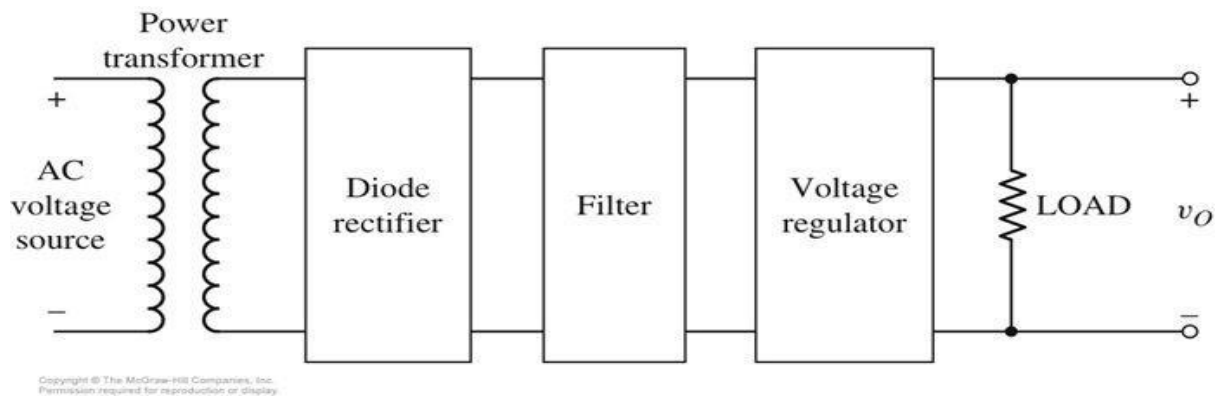
Fig 2.3: Block diagram of an AC-to-DC converter.

A DC power supply is required to bias all electronic circuits. The DC output V_o will usually be in the range of 3-24Vdepending the particular electronic application. Here diode is very useful because characteristics of a silicon diode is non-linear that is, current exists for one voltage polarity but zero for the opposite polarity.

There are many ways of rectification process. We will go through them all later. The half-wave rectifiers are the simplest power electronics circuit used in radios for low-cost power supplies. But for most power applications, half wave rectification is insufficient for the task. The output is quiet difficult to filter because the harmonic content of the waveform is very large. It is very easy to understand the basic principles with this rectifier. Let's see the basic principle of a half-wave rectifier.

2.1.1 Half Wave Rectifier

During each positive half cycle of the sine wave, the diode is forward biased as the anode is positive so the current flows through the diode. The diode is in reverse biased during the negative half cycle which blocks the current flow. This way all positive half cycle waveforms are made unidirectional. Using a capacitor parallel to the load the amount of ripple voltage can be reduced and a steady current is produced

2.1.2 Full Wave Rectification

The full wave rectification uses both positive and negative half cycles of the sine wave. In case of full wave rectification, two diodes are used of which one conducts during the positive half cycle and the other conducts during the negative half cycle. The important point is that the current through the load flows in the same direction thus the output is unidirectional. Turning on a diode depends on the polarity of the cathode voltage and turning it off depends on the device current. Three terminal devices such as Thyristor, BJT and MOSFET etc. can be used to control the output voltage. The conversion of AC-DC will take place when input is an AC supply and the output is a DC load for example battery charging, DC motor, electrolysis, electromagnets etc. In designing a rectifier, two important parameters must be specified: the current handling capability and the Peak Inverse Voltage (PIV) the diode must withstand without breakdown. PIV is specified by the manufacturer.

Chapter-03

Different Types of AC to DC Converter

3.1 Classification

Diode rectifiers are classified into two types: Single-Phase and Three-Phase. Rectification can be done in three processes: Half wave rectification, Full wave rectification and Bridge rectification.

Single-Phase Half wave rectification is done with a single diode. But the output is not efficient enough for power applications.

Single-Phase Full wave rectification can be done in various ways. These are:

1) Full Wave transformer using Center-tap transformer
2) Dual polarity Full Wave Center-tap rectifier
3) Full Wave Bridge rectifier

Other than single-phase rectification, the following configurations are used:

1) Three phase full wave bridge rectifier
2) Six phase full wave bridge rectifier
3) Poly-phase rectifier circuit 3-phase 2-way 12-pulse(3Ph2W12P)

Again, through the advancement of rectification processes, a variety of converters have been created according to the necessity. All of them together can be arranged in the following way:
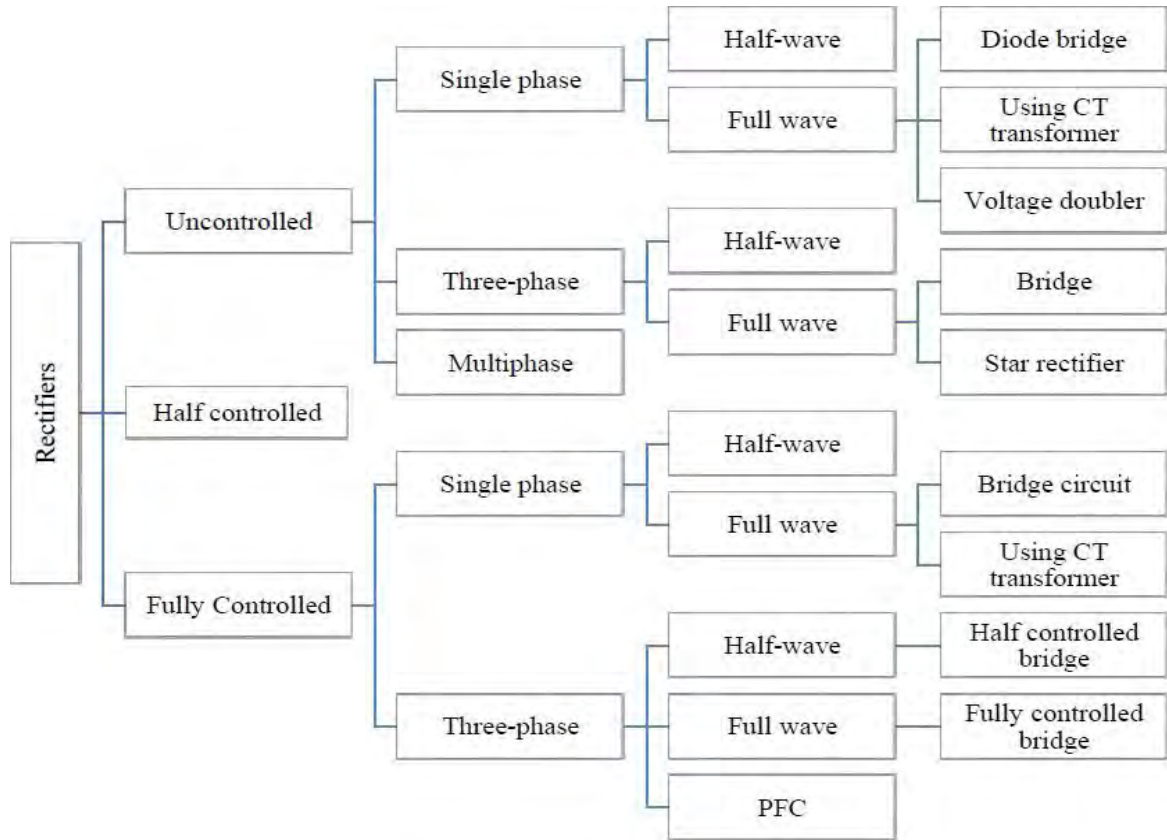

Fig 3.1: Classification of AC-DC converters.

Furthermore, both single phase and three phase converters of controlled rectifier is divided into three types: semi-converter, full converter and dual converter.

There have been many topologies of AC- DC rectifiers since the evolution of diodes and thyristors.Usually uncontrolled and line-commutated rectifiers use diodes.Most of them have fixed frequency input AC voltage and fixed DC output. Controlled rectifiers or Phase controlled rectifiers have control on switching devices and usually consists of a thyristors.The thyristors act as switch (achieved by suitable gate trigger pulse). Apart from the above classifications of AC-DC converter, there are many advanced and hybrid structure of construction proposed by different engineers and researchers which popular in the industry.

3.1.1 Single-Phase Half Wave Rectifier

From the name we can understand that half of the input wave is rectified, other half is wasted. The basic things of the half wave rectifier is, it consist a step down transformer, a diode and a load resistance is also connected with the transformer to the cathode end of the diode. The main supply voltage comes from the transformer which voltage can be increased or decreased. In the most cases step down transformer are used in AC.
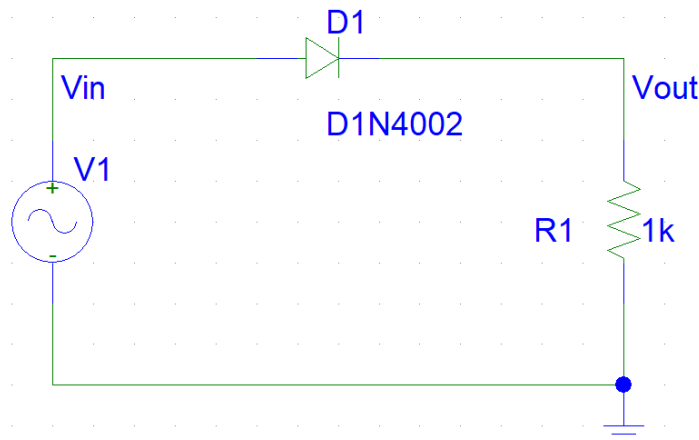

Fig3.2: Single Phase Half Wave Rectifier

Diode takes the decreased AC voltage which is connected serial to the secondary winding of the transformer. As diode works in one direction, it only allows current in forward bias and not allows the reversed bias current. Eventually we get the DC voltage from the diode and give to the load resistance. Both positive and negative cylcles are considered as input. In the positive half cycle the voltage and current comes from the secondary winding and goes through the diode. As diode is in forward bias postion it closes and allows cuurent flowing in clock wise direction from anode to cathode. On the other hand the negative half cycle current will flow in the anti-clock-wise direction. As earlier we discuss, diode is one directional then it is considered as reversed biased, open up and does not conduct. As no current is flown in the negative bias positon from anode to cathode, we do not get any power from the load resistance. Small amount of current is flown from the diode but it is almost negligible.
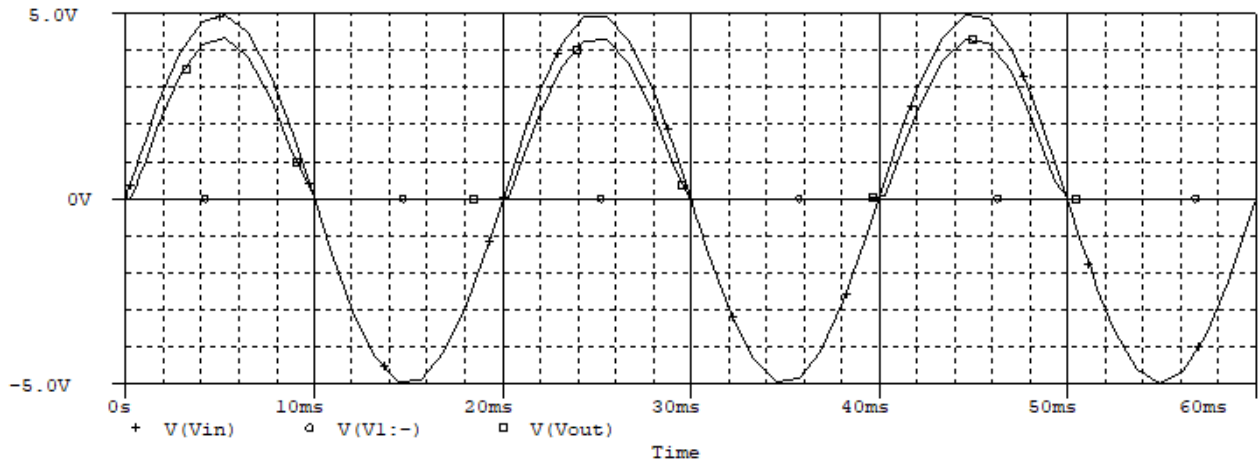
Fig3.3: Input Output Waveform of Single Phase Half Wave Rectifier

If we try to calculate the efficiency of a half wave rectifier, we get:

Efficiency $\eta = P_{DC} / P_{AC}$

DC power delivered to the load, $P_{DC} = I^2_{DC} R_L = (I_{max/pi})^2 R_L$

AC power input transformer P_{AC} = Power dissipated junction in diode + Power dissipated in load

$$= I^2_{rms} R_F + I^2_{rms} R_L$$

$$= (I^2_{MAX}/4) (R_F + R_L)$$

Therefore, rectification efficiency $\eta = P_{DC} / P_{AC}$

$$= \frac{(Imax/pi)2 \quad RL}{(I2MAX/4) \ (RF + RL)}$$

$$= \frac{0.406}{1+RF \ /RL}$$

If R_F is neglected, the efficiency of output DC power is 40.6% [PIV = v_s].

Alsohalfwaverectifierdoesnotfunctionproperlywhentheinputsignalisverysmallsuchas 100mV signal cannot be rectified. This is minimized using an Op Amp called precision rectifier.

11

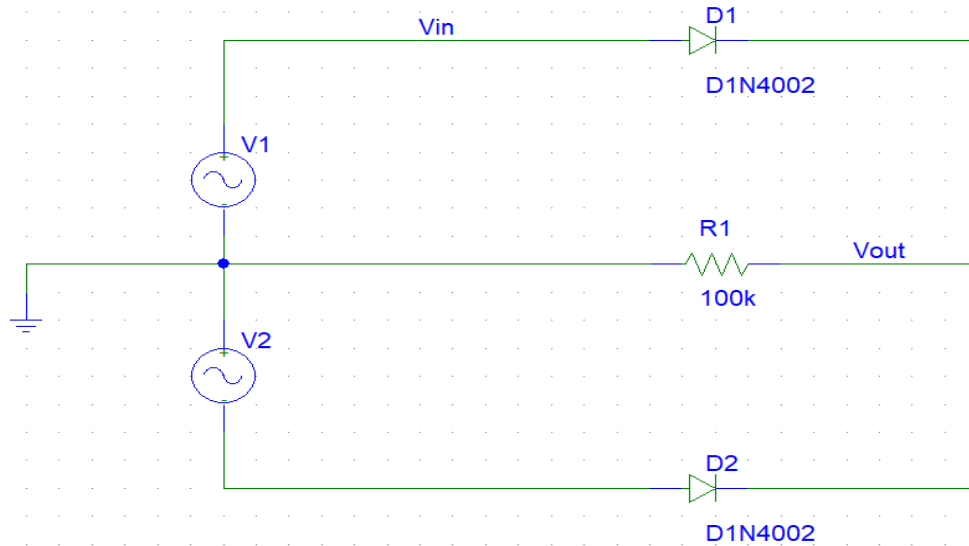### 3.1.2 Single-Phase Full Wave Transformer using Center-tap Transformer

Fig 3.4:Single-Phase Full Wave rectifier using center-tap transformer Circuit

This circuit's operation is easy to understand one half-cycle at a time. In the Fig above, the secondary winding is center-tapped with equal voltage v_s indicating the polarities. When the input line voltage (primary) is positive, both indicated v_s will be positive. In the first positive halfcycleD_1willconductandD_2willbereversedbiased.Thecircuitbehaveslikeahalf-wave rectifier and the output is identical with the output of half-wave rectifier. During the negative half cycle, both the labeled v_s will be negative. So, D_1 will be cut-off and D_2 will conduct. The current flows through $D_2$and the load R back to the center-tap. Again the circuit behaves like a half-wave rectifier. The important point is that the direction of the current through R is the same. Thus the output is uni-polar and it is assumed that there is a voltage drop V_D conducting through the diode.

To find out the PIV, we have to calculate positive and negative half cycles separately. In case of positive half cycle, the diode $D_1$is conducting and $D_2$is cut-off. The voltage of the cathode at $D_2$is v_o and at its anode $-v_s$. the reverse voltage across D_2willbe

($v_o + v_s$), which will reach its maximum when the output is at peak of (V_S - V_D) . Thus,
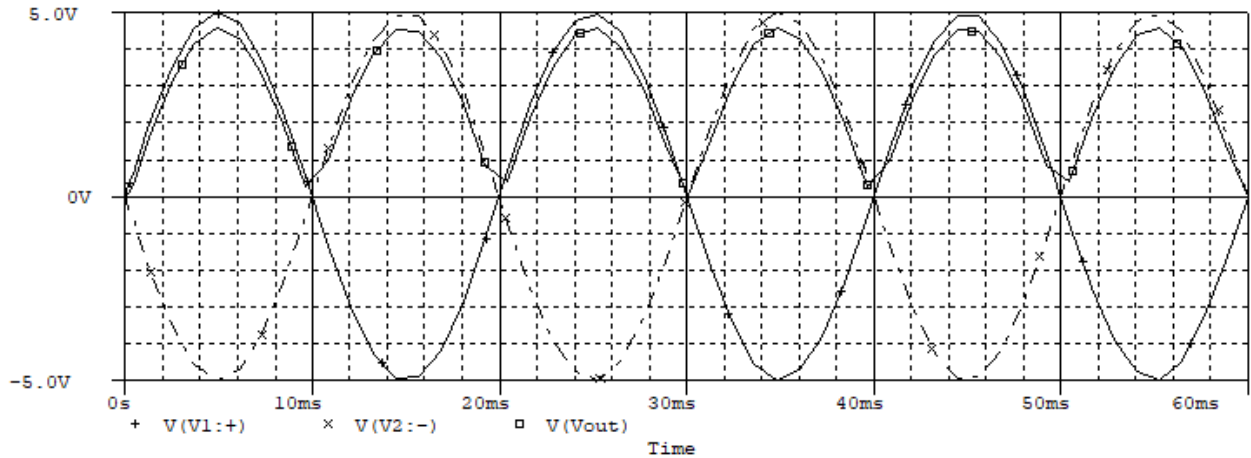
$$PIV= 2V_S - V_D$$

Fig 3.5: Input Output Waveform of Single Phase full wave rectifier using center-tap transformer Circuit

Which is approximately twice the value of half-wave rectifier.

There is no DC saturation problem in the transformer core because there is no DC cuurent flowing. If in the Fig above,$V_s=V_m \sin\omega t$, where V_m is the amplitude of V_s, the average output voltage

$$V_{DC}= \frac{2}{T} - \int_0^{\frac{T}{2}} V_m \sin\omega t \, dt = \frac{2V_m}{\pi} = 0.6366 \, V_m$$

3.1.3 Single-Phase Dual Polarity Center-tap Full-Wave Rectifier

In this circuit the output is of dual polarity. The full wave center-tapped rectifier polarity at the load may be reversed by changing the direction of diodes. We can also put the reversed diodes parallel to the positive output rectifier. The connectivity of the diodes is similar to the connection bridge rectifier.
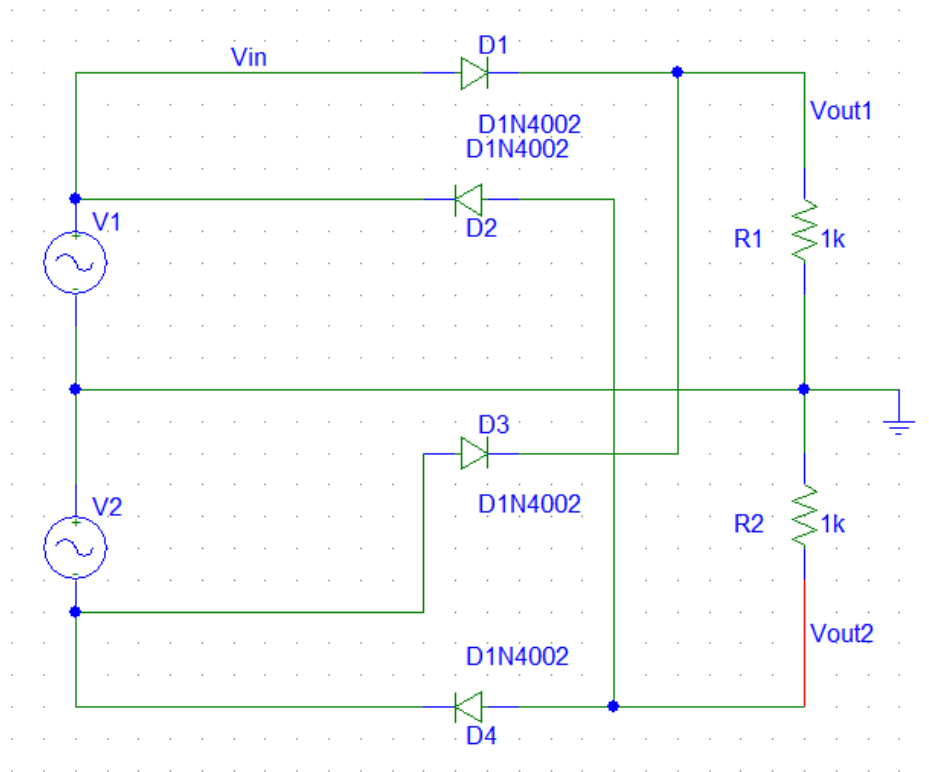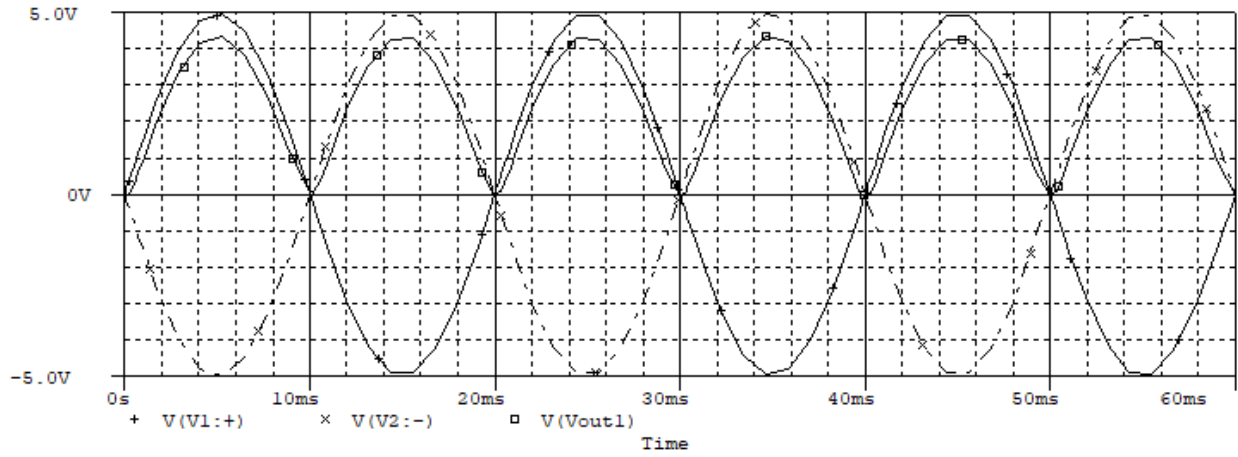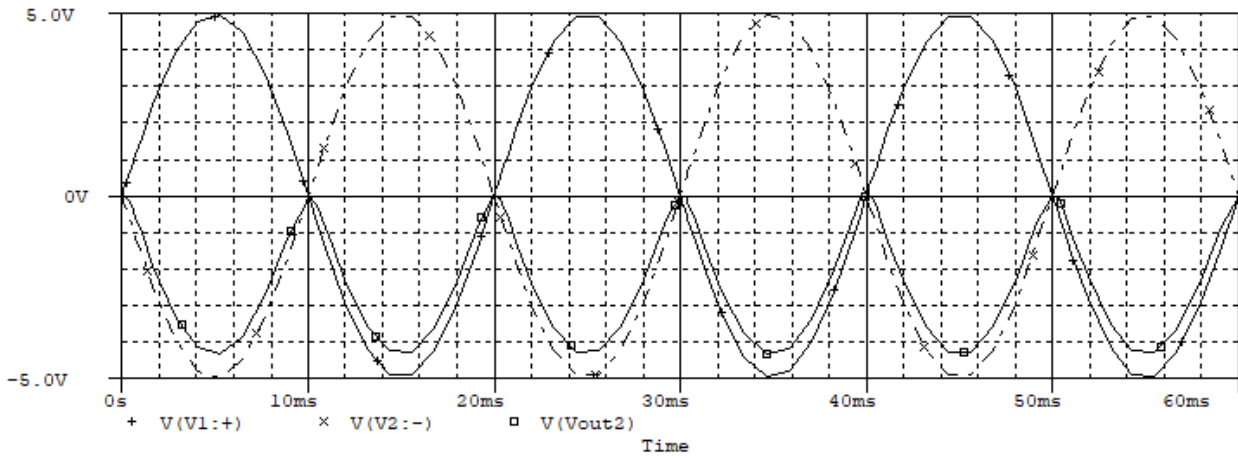

Fig 3.6: Dual polarity center-tapped full wave rectifier circuit.

(a)

(b)

Fig 3.7: Input Outout Wavefrom of Dual polarity center-tapped full wave rectifier
(a) positive output (b) negative output

3.1.4 Single-Phase Full Wave Bridge Rectifier

Full wave bridge rectifier is more popular than others. The bridge rectifier is commonly used in industrial applications.
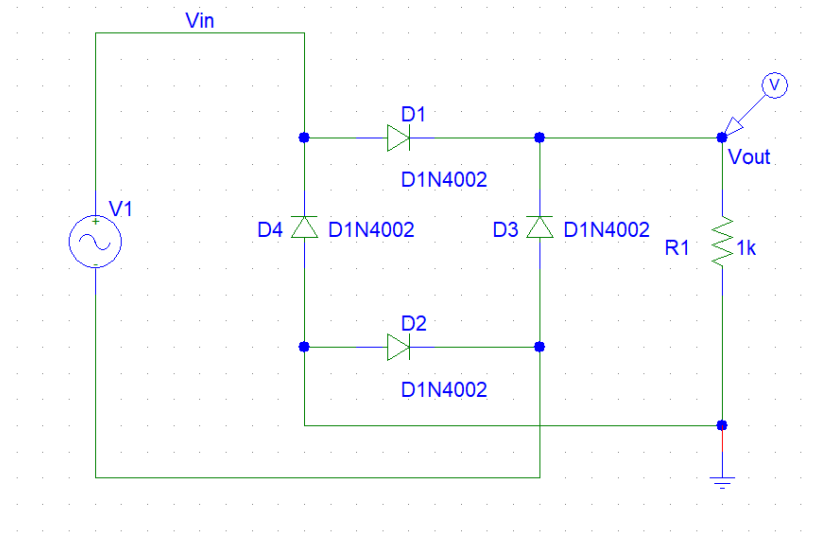

Fig 3.8: Single-Phase Full Wave Bridge Rectifier

The circuit is connected with an AC source. It behaves almost same as the previous system. The only difference is it has four diodes. During the positive half cycle, the current conducts through D_1, the load R and then D_2. At this instant D_3 and D_4 remain off because they are in reverse biased. Point to be noted that, the two diodes are in series connection so there is voltage drop at both diodes. That's why the output voltage is lower than the input. During the negative half cycle, the source voltage v_s will be negative. The current then flows through D_3, the load R and D_4. At this time the diodes D_1 and D_2 are reverse biased. The important point is that, the direction of the current flow through the load R did not change in the negative cycle. Thus the voltage v_o is always positive.
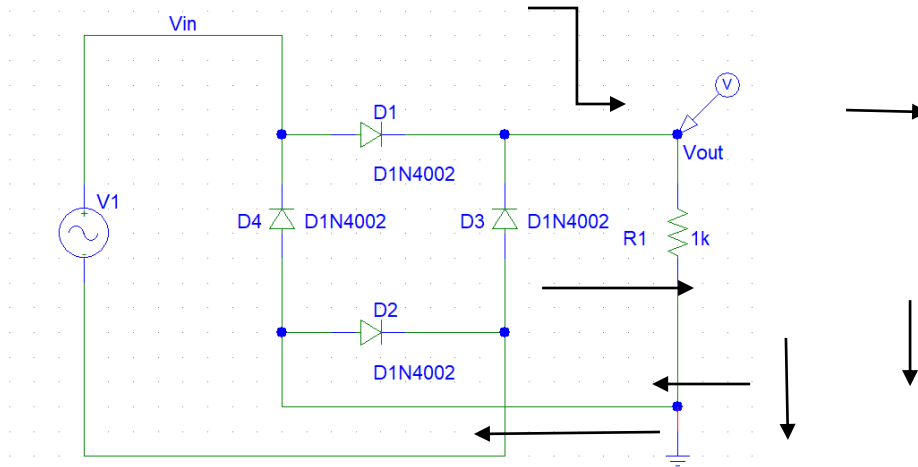
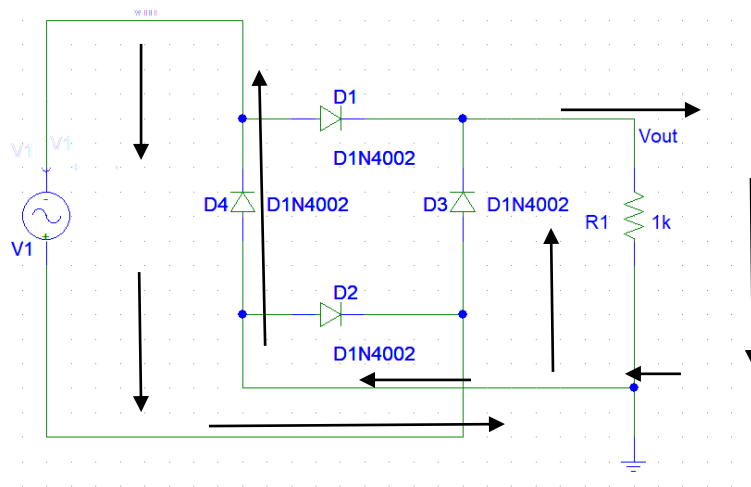Fig 3.9: Full wave rectifier showing positive half cycle current flow

Fig 3.10: Full wave rectifier showing negative half cycle current flow.
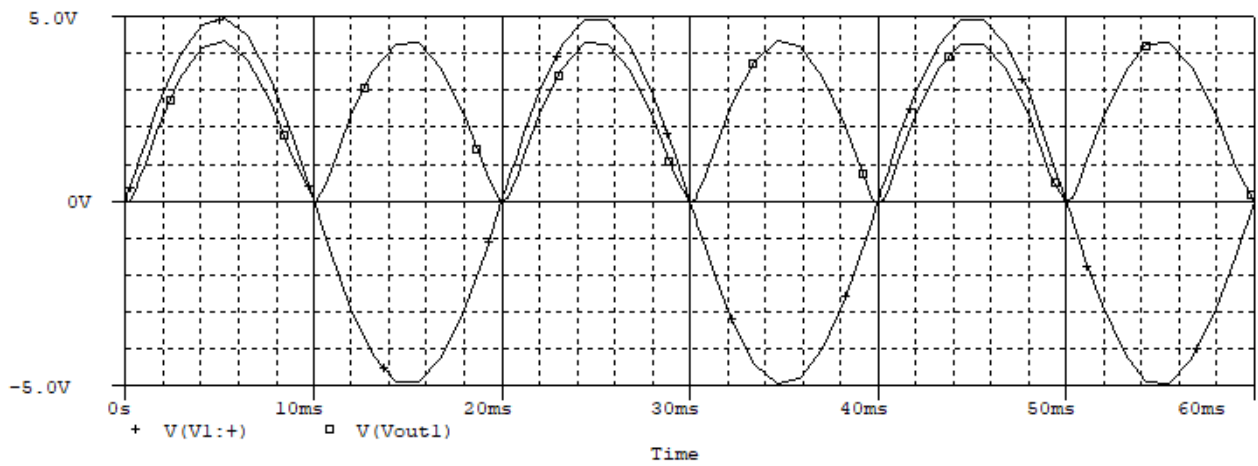
Fig 3.11: Input output waveform Single-Phase Full Wave Bridge Rectifier

To determine PIV, consider the circuit during the positive half cycle. The reverse voltage across D3 can be determined from the loop formed by D3, R, D2 as

$V_{D_3}(\text{reversed}) = V_o + V_{D_2}(\text{forward})$

Thus the maximum value of v_{D3} occurs at the peak of v_o given by PIV =

$V_s - 2V_D + V_D = V_s - V_D$

This is an advantage of bridge rectifier as the PIV is half of the value of a center-tapped rectifier. One more advantage is that only half as many turns are required for the secondary winding of the transformer. For these reasons the bridge rectifier is popular.

However, there are some disadvantages of this rectifier. There is voltage drop at the output due to higher number of diodes in the circuit as we have found in above waveforms.

Using Filter Capacitor
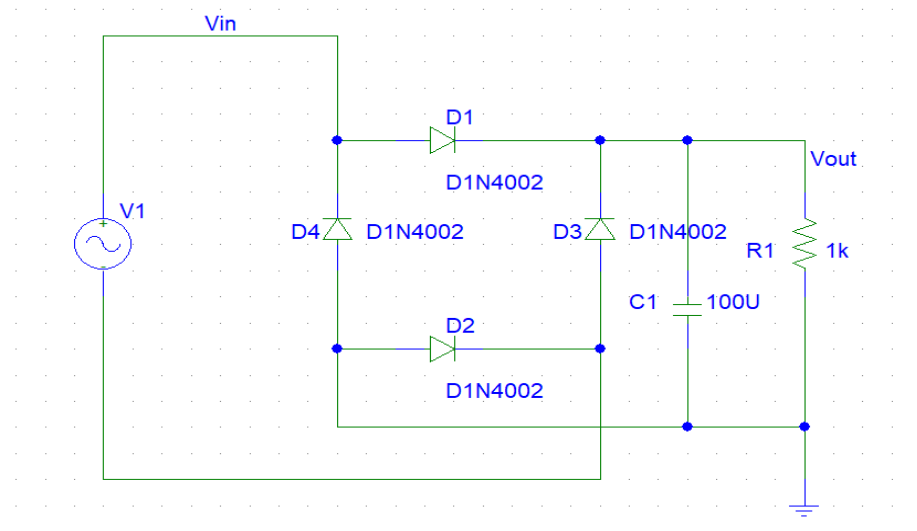
Fig 3.12: Single-Phase Full Wave Bridge Rectifier with filter capacitor.

The output waveform is uni-polar i.e. a DC voltage but to reduce the variations a capacitor parallel to R is used. For specific values of C and R, the ripple voltage can be controlled. We want the ripple factor as low as possible to reduce the variation of the output voltage. The amount of ripple in power supply is often indicated by:

$$\text{Ripple Factor} = \frac{\text{RMS value of AC component}}{\text{DC or average value of the outpu}}$$
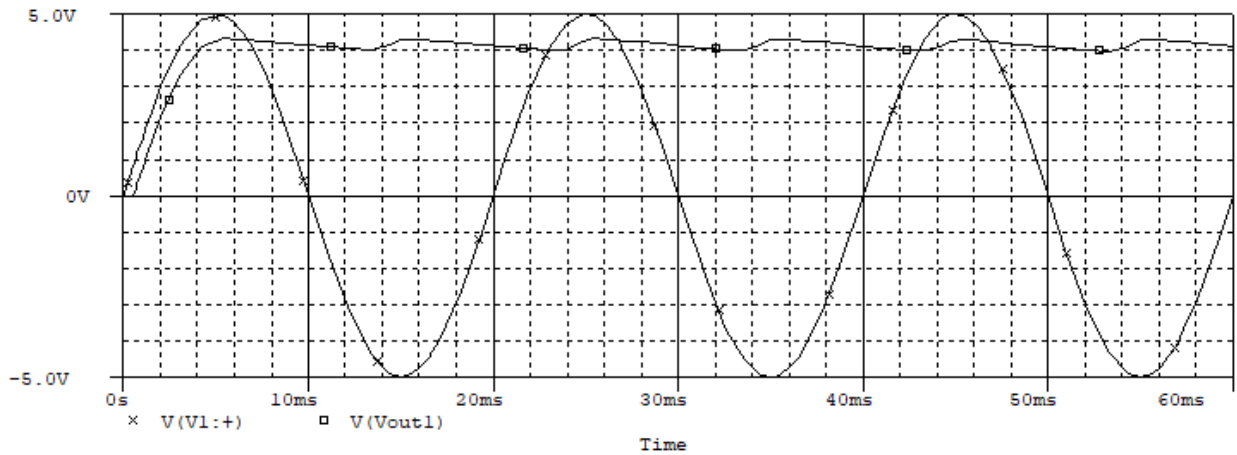
Fig 3.13: Input Output Waveform of Single-Phase Full Wave Bridge Rectifier with filter capacitor.

Aluminum electrolyte capacitors are widely used and have capacitance of 100μF or more. A lowcapacitancewillnotbeeffectivesocapacitorisconnectedinparalleltoincreasethevalue as long as the load current is not too large. The ripple voltage can be written as,

$V_{ripple} = \dfrac{Vp}{2fCR}$ for full wave rectifier. The value of ripple voltage of half wave rectifier is half

the value of full-wave rectifier. A more effective method of reducing the ripple voltage is the addition of π-filter (pi-filter) at the output of rectifier as shown in the Fig. This low pass filter consists of two smoothing capacitors, as well as a choke to provide high impedance to the AC ripple.

3.1.5 Three-Phase Bridge Rectifiers

A three phase bridge rectifier is commonly used in high power applications. An example of three phase rectifier circuit is given below.
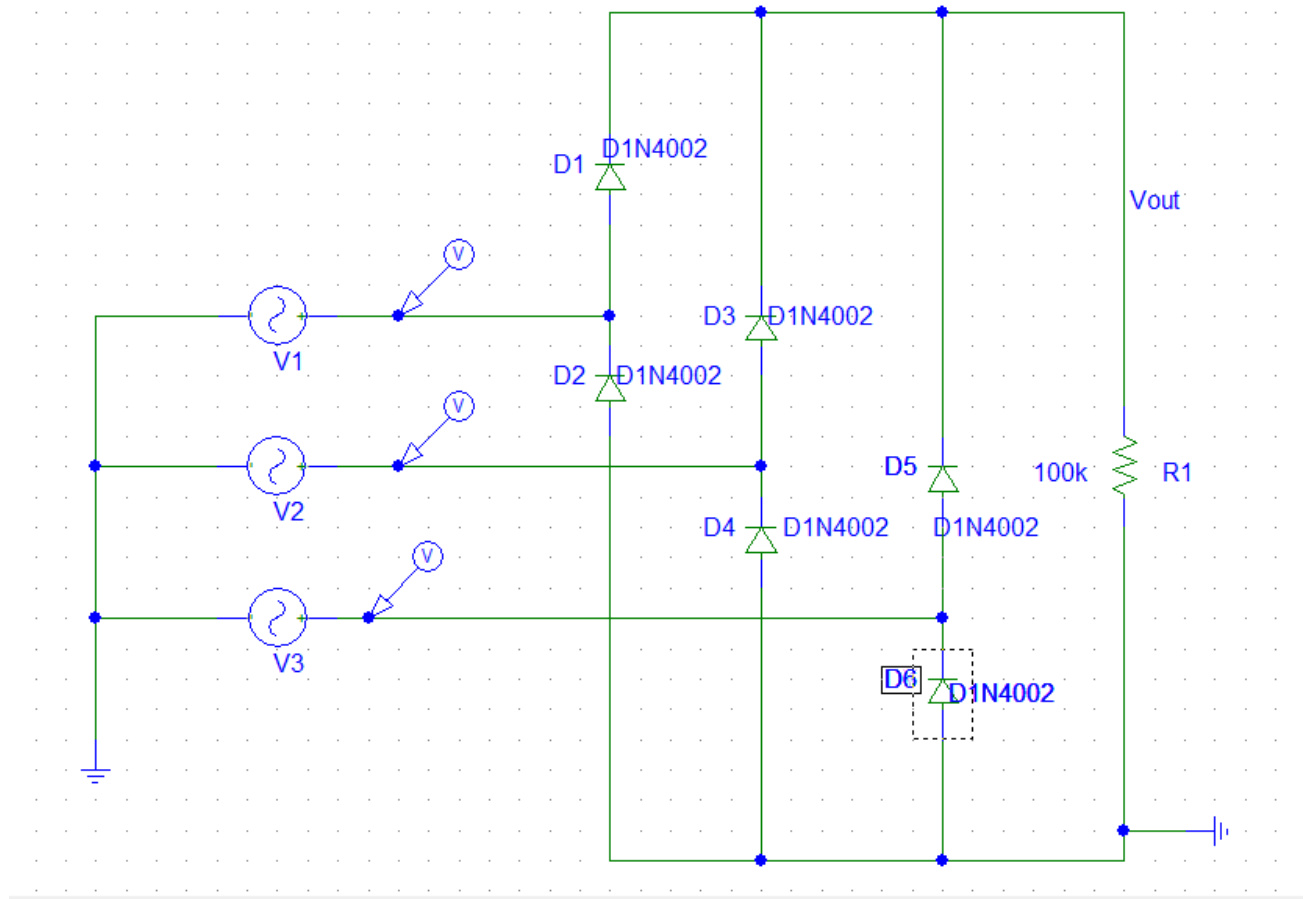
Fig 3.14: Three phase bridge rectifier circuit

This system can operate with or without a transformer. There are six diodes used in this circuit and gives six-pulse ripples on the output voltage. In this case, a pair of diodes remains on and other four diodes remain off for each cycle. The conduction sequences are: $D_1 - D_2$, $D_3 - D_2$, $D_3 - D_4$, $D_5 - D_4$, $D_5 - D_6$ and $D_1 - D_6$.

The pair of diodes which are connected between that pair of supply lines having the highest amount of instantaneous line-to-line voltage will conduct. We know that the line voltage is $\sqrt{3}$ times the phase voltage. The diodes are numbered in ordered sequence is 120°each.
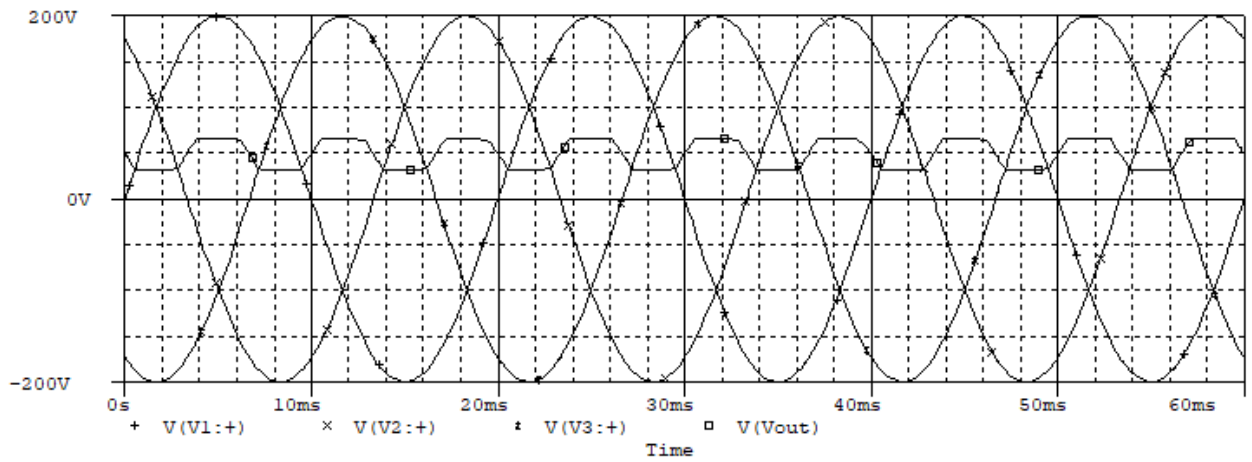
Fig 3.15: Input Output Waveforms and conduction of times of diodes

This type of converter is extensively used in high power variable speed industrial DC drivers. These types of converters have higher output voltage ripple frequency. From the Fig we can understand that the output is smoother and variation is less than the single phase output.

3.1.6 Six-Phase Full Wave Bridge Rectifier Circuit

A Six-phase full wave bridge rectifier can be operated from a 3-phase supply using a transformerwith3center-tappedsecondarywindingwithallthecenter-tapconnectedtogether.

The output voltage has a mean voltage $0.955V_{SM}$(less than the voltage drop in the diode).The ripple factor has a very small value and a fundamental frequency of six times the supply frequency. An example of 6-phase full wave rectifier is given below.
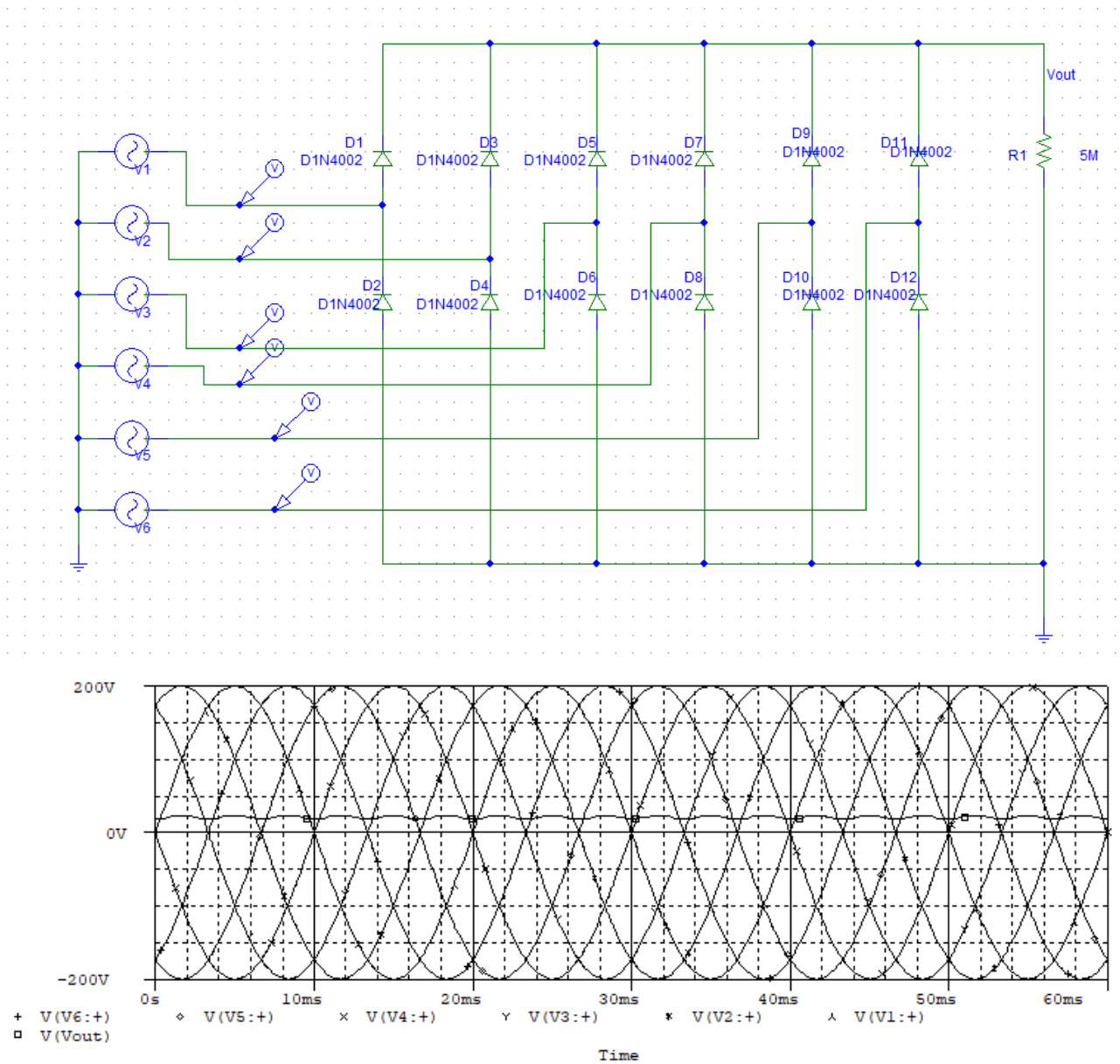
Fig 3.16: (a) Six-phase full wave bridge rectifier circuit (b) Input Output Waveform

3.1.7 Poly-Phase Circuit Rectifier

In poly-phase circuits it is possible to obtain more pulse than twice the number of phases in a rectifier circuit. If a transformer connected in Y-Δ or Δ-Y connection, it will have 30° phase shift while a transformer of Y-Y or Δ-Δ will not. There is less superposition result in ripple voltage due to connection below. It gives 12 pulses per 360° instead of six.
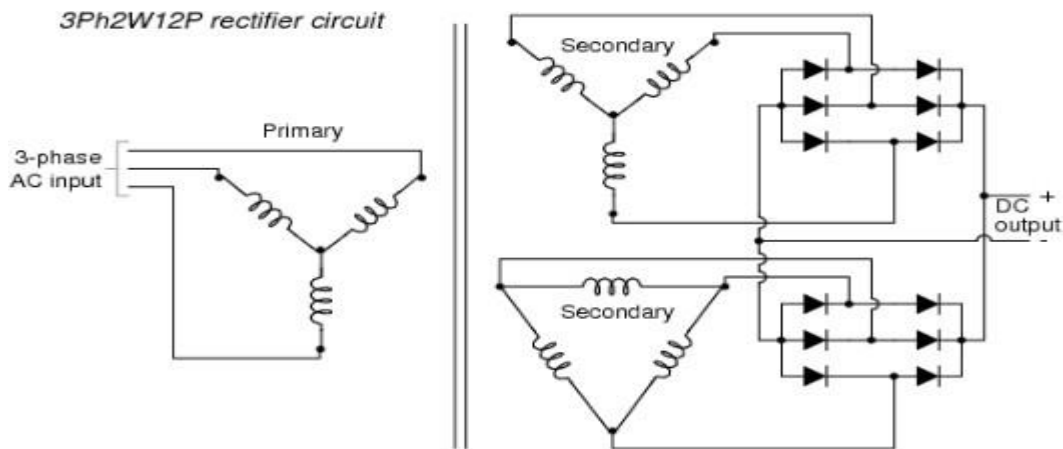
Fig 3.17: Poly-phase rectifier circuit; 3-phase 2-way 12-pulse (3Ph2W12P).

3.1 Phase Controlled Rectifiers

In case of phase controlled rectifiers, thyristor is used in place of diode. Their circuit construction is almost same but the output waveform is different. Let's analyze the rectifiers with thyristors.

3.2.1 Single-Phase Half Wave Rectifier

A single thyristor or SCR is connected between the secondary winding of the transformer and load can be resistive or inductive. The primary side is connected with a single phase supply.

Fig 3.18: Single phase Half Wave Rectifier with waveforms. (a) Source voltage waveform. (b) Output waveform if load is resistive. (c) Output waveform if load is inductive.

During the positive half cycle, T is forward biased. When it is triggered at some firing angle it starts conducting current at the load. This SCR is uni-directional; it turns off during negative half cycle. So the output is produced only for the positive half cycle. The output is controlled by varying the firing angle to the gate terminal.
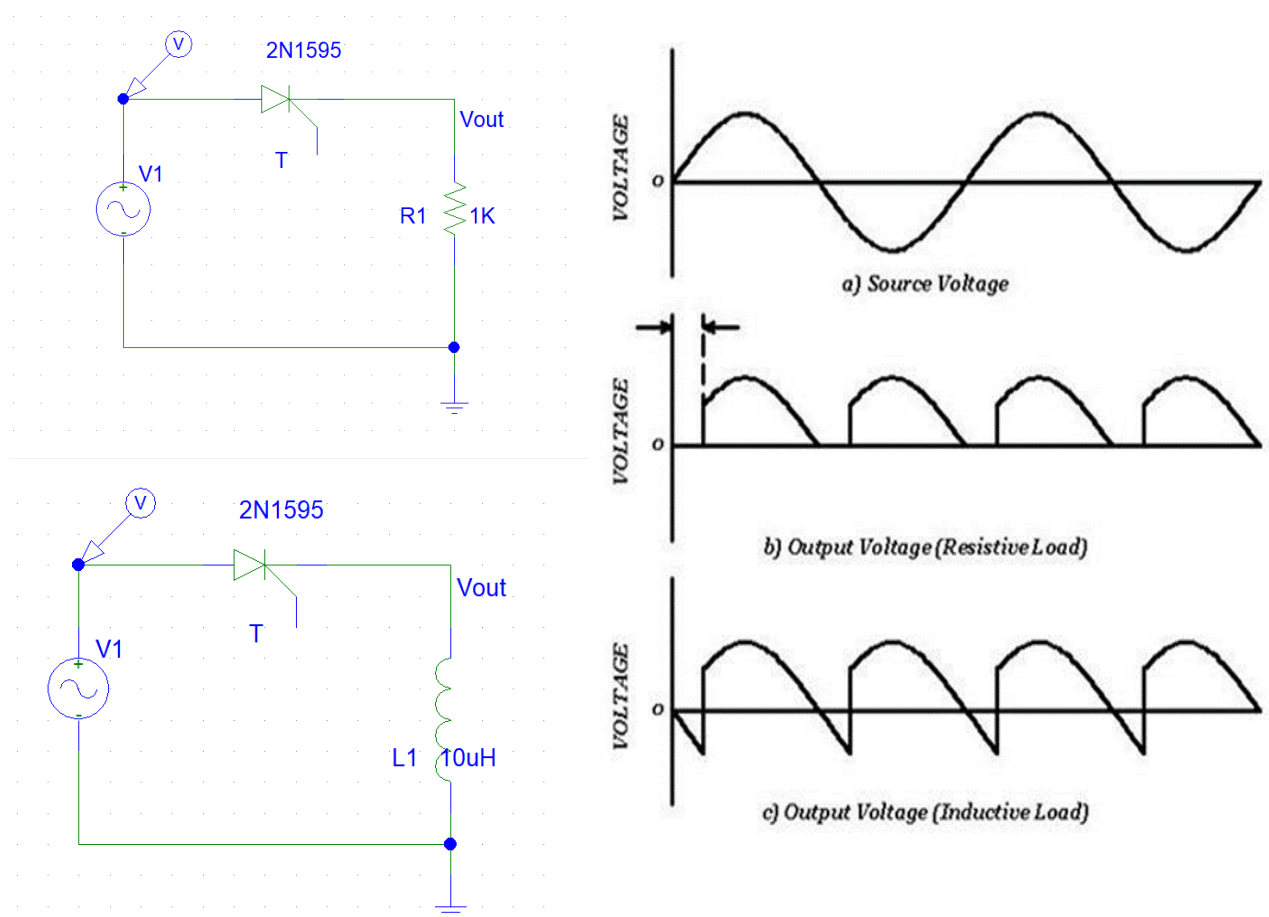
If V_m is the peak input voltage, the average output voltage V_{DC}:

$$V_{DC} = \frac{1}{2\pi} \int_\alpha^\pi Vm\ sin\omega t\ (\omega t) = V_m/2\pi\ (1+ \cos\alpha)$$

The average output becomes maximum when α=0. We can write,

$$V_{dm} = V_m/\pi$$

3.2.2 Single-Phase Full Wave midpoint Converter

This can rectify both positive and negative half cycles of the input. Its configuration is almost like the center-tapped transformer with two thyristors.
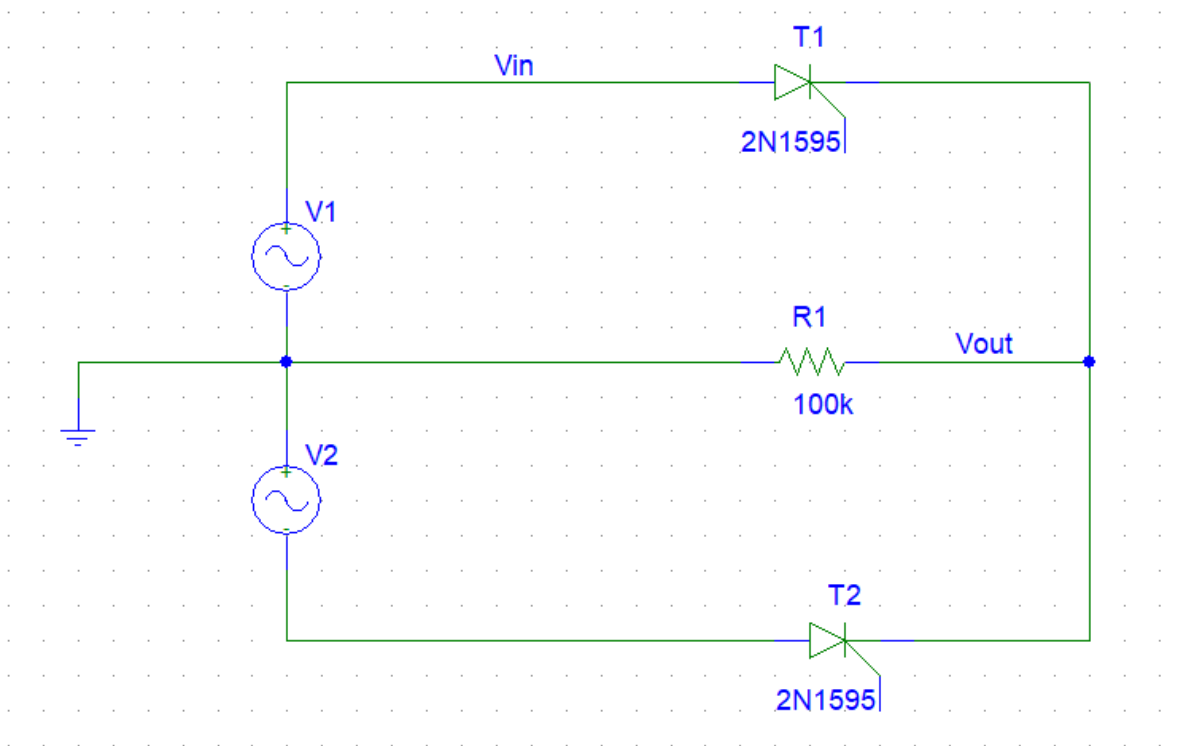
Fig 3.19: Single phase midpoint converter

During the positive half cycle, T_1 is forward biased and T_2 is reversed biased. When T_1 is triggered, the supply voltage appears across the load. It conducts till 180 degree of input supply and turns off for natural commutation. During the negative half cycle it is vice-versa. The load can be resistive or inductive. In this system the output voltage is twice of the single This type of converter is required when one of the terminals on the DC side has to be grounded. A center-tapped transformer with VA rating twice that of load is required. Also high voltage thyristors are required for this converter.

3.2.3 Single-Phase Full Wave Bridge Rectifiers

There are 4 SCRs in this circuit. This rectifier produces controllable DC by varying the conduction of all SCRs.
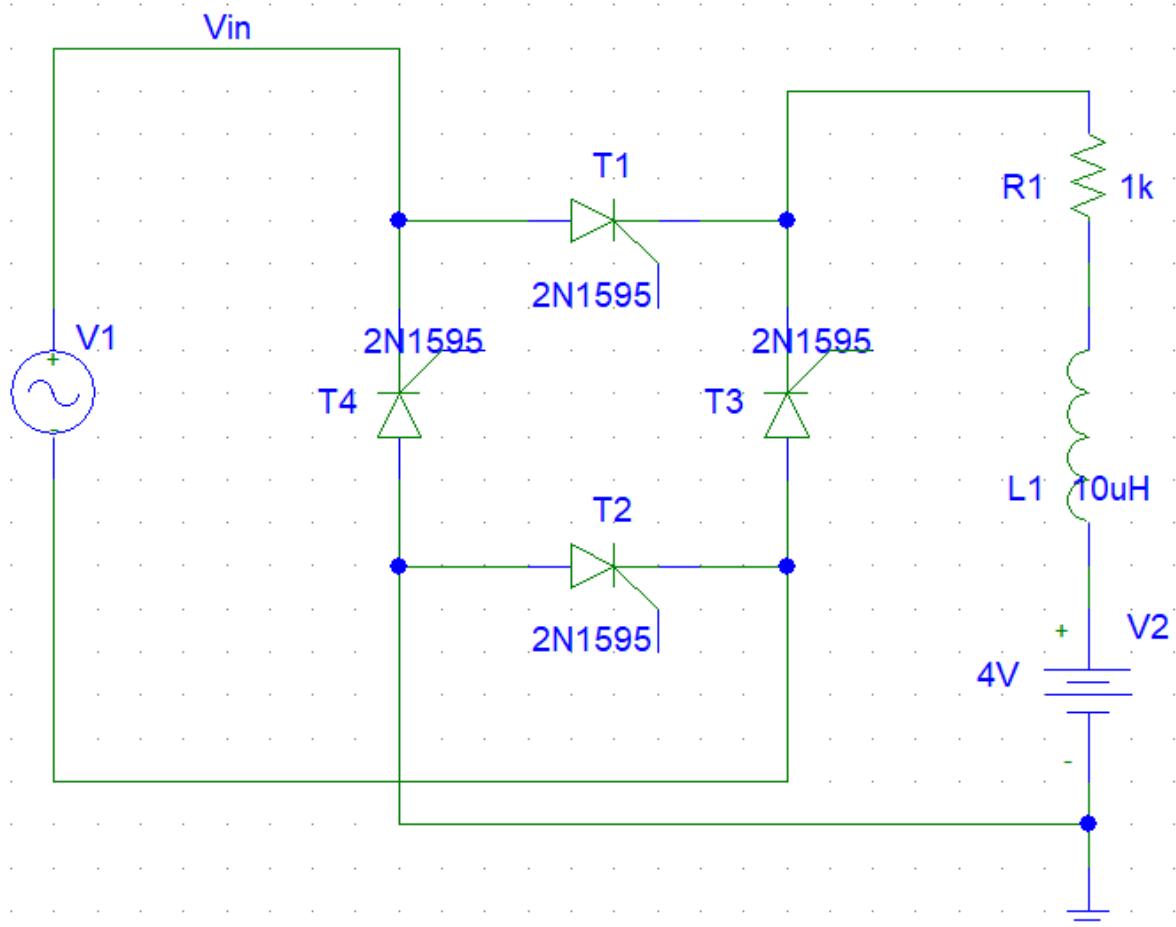
Fig 3.20: Single phase full converter with waveforms.

This circuit arrangement is shown in the above Fig 3.20 with highly inductive load so that the current through the load is continuous and ripple free. During the positive half cycle T_1 and T_2 are forward biased. When these two thyrsistors are fired simul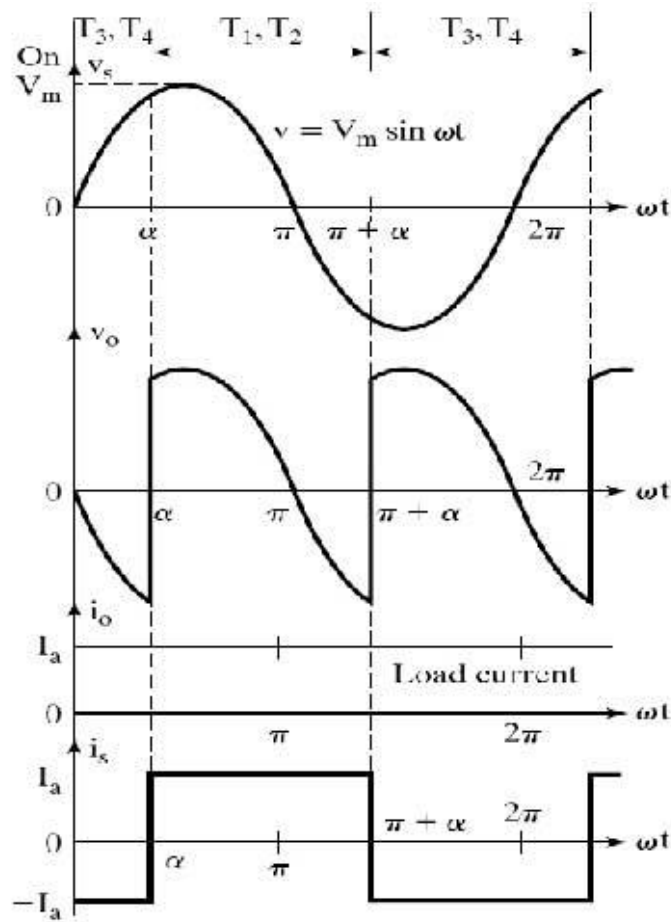taneously at $\omega t = \alpha$, the load is connected to the input supply through T_1 and T_2. Due to the inductive load, T_1 and T_2 continue to conduct beyond $\omega t = \pi$ even though the input is negative.

For the negative half cycle of the input voltage the other thyristors T_3 and T_4 are forward biased and the others are off. The output waveforms are shown in the Fig above. The voltage v_s and the current i_s is positive during the period of α to π. The converter is said to be operated in rectification mode. During the period of π to $\pi + \alpha$, v_s is negative and i_s is positive and the reverse power flows from load to the supply. This converter is said to be operated in inversion mode.

The average output voltage can be found, $V_{dc} = 2/2\pi \int_{\alpha}^{\pi+\alpha} Vm\ sin\omega t\ (\omega t) = \dfrac{2Vm}{\pi} cos\alpha$

3.2.4 Three-Phase Half Wave Rectifier

The 3-phase converters provide higher average output voltage. The frequency of the ripples on the output voltage is higher compared with the single phase converters. Therefore, smoothing out of the output voltage and current is simpler. For these reasons,3-phaseconvertersareused extensively in high power variable speed drivers. Three single phase converters are connected to make 3-phase half wave converter as shown in the Fig3.21.

When T_1 is fired at $\omega t = \pi/6 + \alpha$, the phase voltage v_{an} appears across the load until T_2 is fired at $\omega t = 5\pi/6 + \alpha$. When T_2 is fired, T_1 is reverse biased because the line-line voltage $V_{ab}(=V_{an}-V_{bn})$ is negative and T_1 turns off. The voltage V_{bn} appears across the load until T_3 is fired at $\omega t = 3\pi/2 + \alpha$. When T_3 is fired and T_2 is turned off and V_{cn} appears at the load until T_1 is fired again and continues the cycle. The Fig (b) above shows the v-i characteristics of the load and it's a two-quadrant converter. The Fig (c) shows the input and output voltages and the current through T_1 for a highly inductive load. For resistive load the current would be discontinuous and $\alpha > \pi/6$. Each thyristor is self-commutated when the polarity of its phase voltage is $3f_s$. This system is not normally used in practical systems because the supply current has DC components. However this system explains the principles of a 3-phase half wave rectification.

If the phase voltage is $V_{an} = V_m \sin \omega t$, the average output voltage for continuous load current,

$$V_{dc} = \frac{3}{\pi} \int_{\pi/6+\alpha}^{\pi/2+\alpha} V_{ab} \ d(\omega t)$$

$$= \frac{3}{\pi} \int_{\pi/6+\alpha}^{\pi/2+\alpha} \sqrt{3} V_m \sin(\omega t + \frac{\pi}{6}) \ d(\omega t)$$

$$= \frac{3\sqrt{3}}{\pi} V_m \cos \alpha$$

Where V_m is the peak voltage. The maximum average output that occurs at delay angle $\alpha = 0$ is
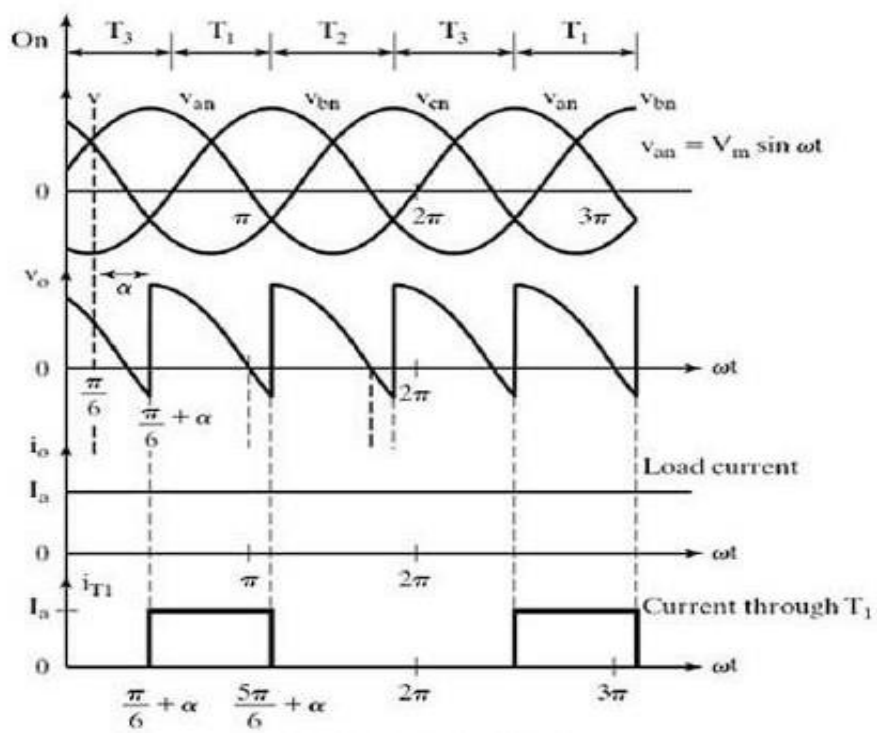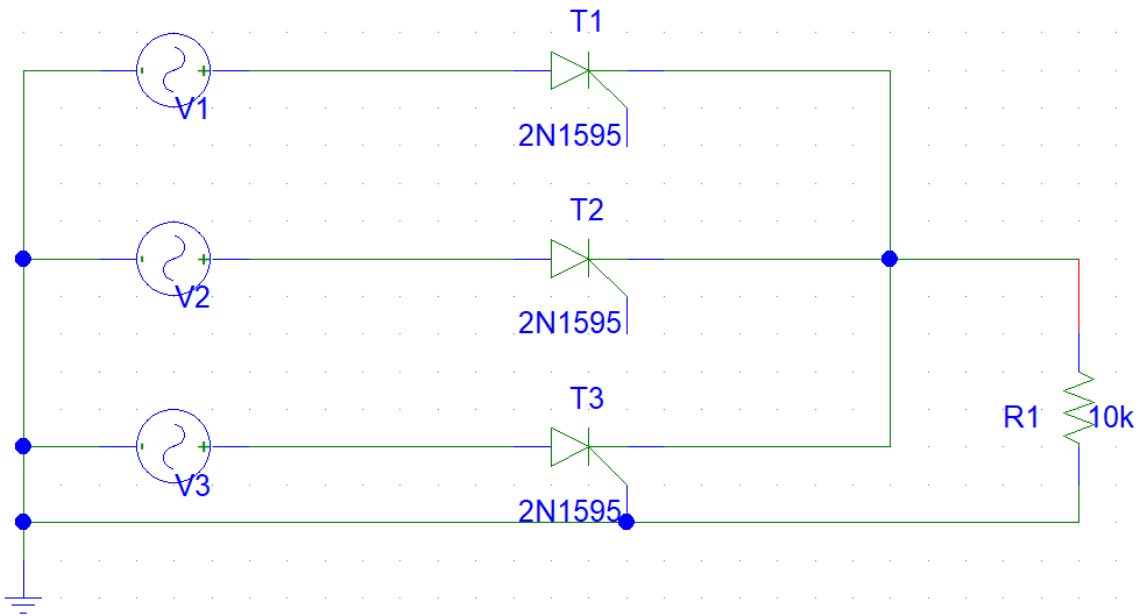
$$V_{dm} = \frac{3\sqrt{3}}{2x} \overline{V}_m$$

Fig 3.21: 3-phase half wave converter with output waveform for inductive load.

And normalized average output voltage is,

$$V_n = V_{dc}/V_{dm} = \cos\alpha$$

The rms output voltage,

$$V_{rms} = \left[\frac{3}{2\pi} [V_m^2 \sin^2 \omega t \, d(\omega t)]^{1/2} \right]$$

$$= \sqrt{3} V_m \left(\frac{1}{6} + \frac{\sqrt{3}}{8\pi} \cos 2\alpha \right)^{1/2}$$

For a resistive load and $\alpha \geq \pi/6$,

$$V_{dc} = \frac{3}{2\pi} \int_{\pi/6+\alpha}^{\pi} V_m \sin \omega t \, d(\omega t)$$

$$= \frac{3 \, V_m}{2\pi} \left[1 + \cos \left(\frac{\pi}{6} + \alpha \right) \right]$$

$$V_n = \frac{V_{dc}}{V_{dm}} = \frac{1}{\sqrt{3}} \left[1 + \cos \left(\frac{\pi}{6} + \alpha \right) \right]$$

$$V_{rms} = \frac{3}{2\pi} \left[\int_{\pi/6+\alpha}^{\pi} V_m^2 \sin^2 \omega t \, d(\omega t) \right]^{1/2}$$

$$= \sqrt{3} V_m \left[\frac{5}{24} - \frac{\alpha}{4\pi} + \frac{1}{8\pi} \sin \left(\frac{\pi}{3} + 2\alpha \right) \right]^{1/2}$$

3.2.5 Three-Phase Full-Wave Converter

This circuit is known as three-phase bridge with highly inductive load as shown in the Fig below. Here the thyristors are fired at an interval of $\pi/3$. The frequency of output ripple voltage is $6f_s$. In this circuit the filtering requirements are less than the half-wave converters. T_1 is on and T_6 is already conducting at $\omega t = \pi/6 + \alpha$. The thyristors T_1 and T_6 are conducting and the line-to-line voltage $V_{ab} = (V_{an} - V_{bn})$ appears at the load during the interval $(\pi/6+\alpha) \leq \omega t \leq (\pi/2+\alpha)$. T_2 is fired and T_6 is reverse biased immediately at $\omega t = \pi/2 + \alpha$. T_6 is turned off due to natural commutation.

Thyristors T_1 and T_2 conduct and line-to-line voltage V_{ac} appears across the load during the interval $(\pi/2 + \alpha) \leq \omega t \leq (5\pi/6 + \alpha)$. If the thyristors are numbered according to the Fig above, thefiringsequenceis12,23,34,45,56and61.TheFigbelowshowsthewaveformsforinput   voltage, output voltage, output current and currents through thyristors.
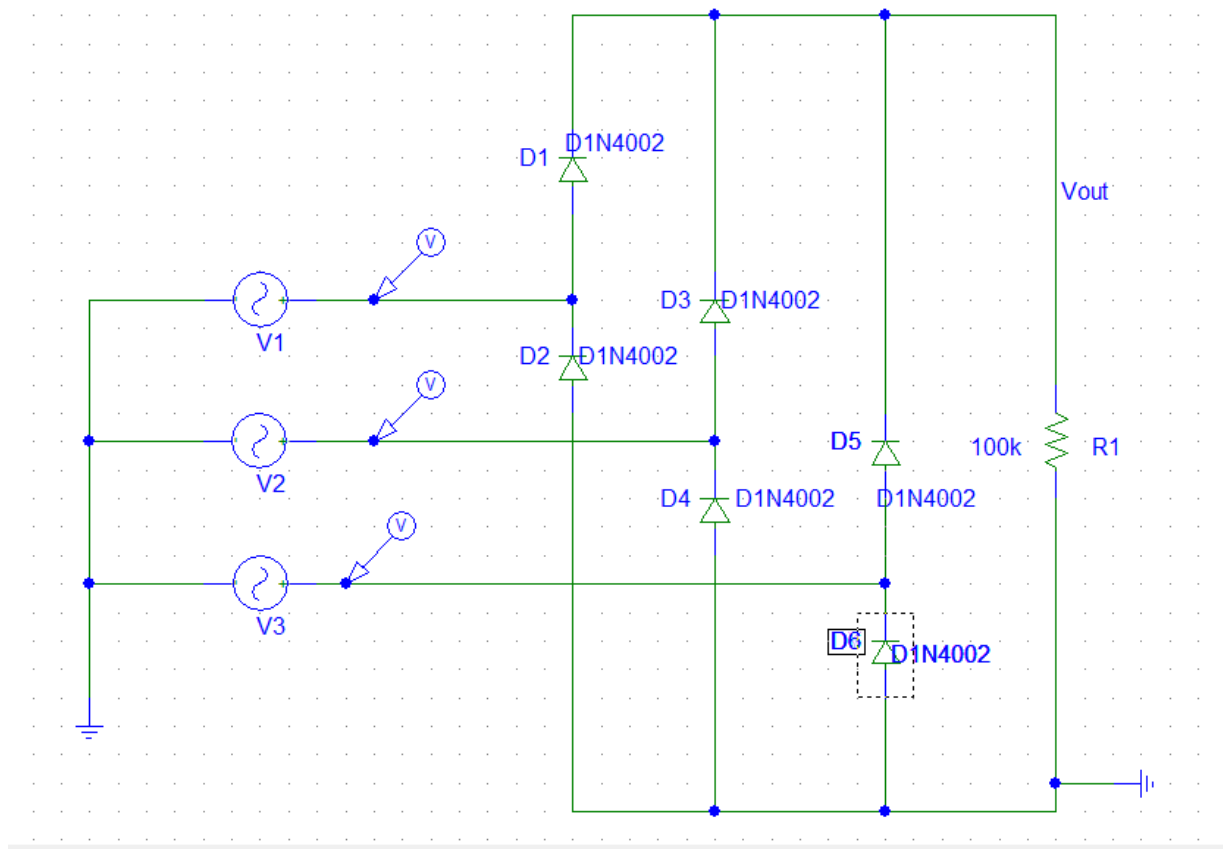

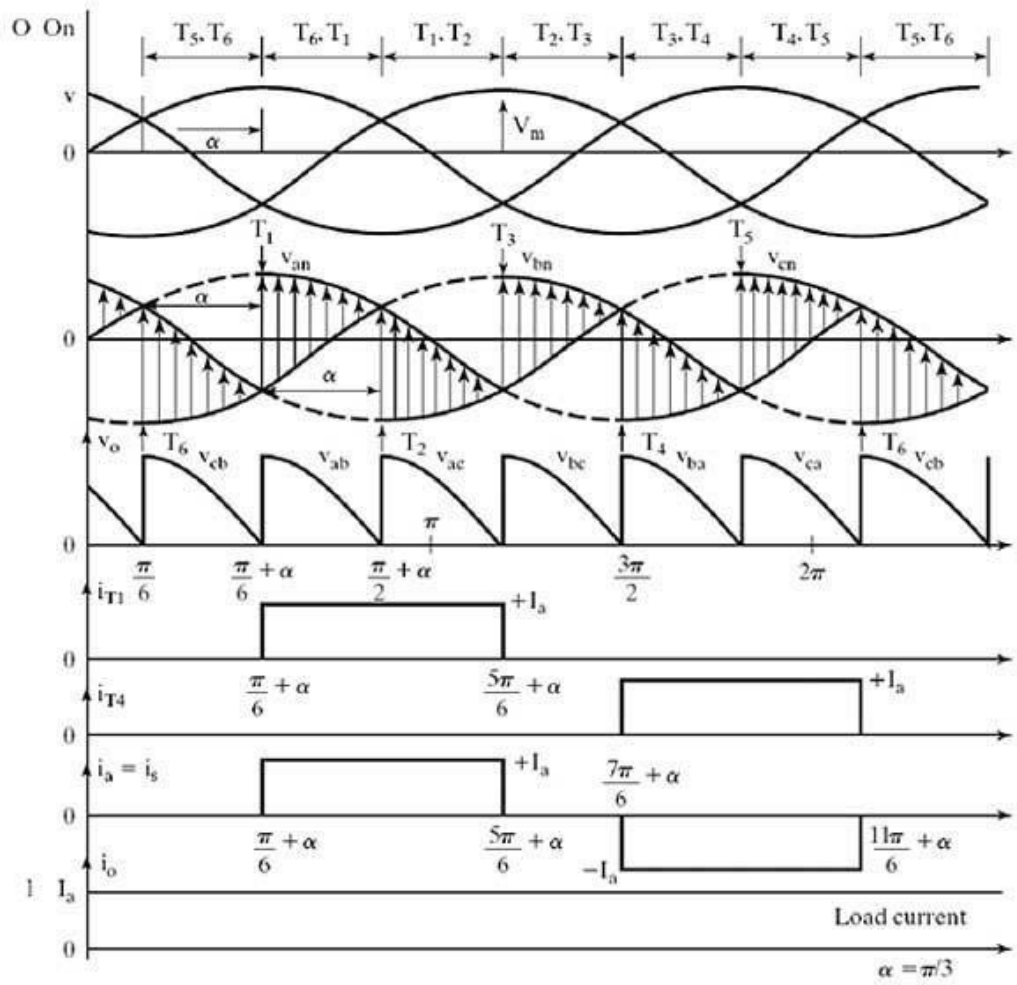Fig: Three-Phase Full-Wave Converter

Fig3.23: The output waveform of three phase full converter.

If the line-to-neutral voltages are defined as,

$$V_{an} = V_m \sin \omega t$$

$$V_{bn} = V_m \sin\left(\omega t - \frac{2\pi}{3}\right)$$

$$V_{cn} = V_m \sin\left(\omega t + \frac{2\pi}{3}\right)$$

The corresponding line-to-line voltages are,

$$V_{ab} = V_{an} - V_{bn} = \sqrt{3}V_m \sin\left(\omega t + \frac{\pi}{6}\right)$$
$$V_{bc} = V_{bn} - V_{cn} = \sqrt{3}V_m \sin\left(\omega t - \frac{\pi}{2}\right)$$
$$V_{ca} = V_{cn} - V_{an} = \sqrt{3}V_m \sin\left(\omega t + \frac{\pi}{2}\right)$$

The average output voltage is found as,

$$V_{dc} = \frac{3}{\pi}\int_{\pi/6+\alpha}^{\pi/2+\alpha} V_{ab}\, d(\omega t)$$

$$= \frac{3}{\pi}\int_{\pi/6+\alpha}^{\pi/2+\alpha} \sqrt{3}V_m \sin\left(\omega t + \frac{\pi}{6}\right)\, d(\omega t)$$

$$= \frac{3\sqrt{3}}{\pi} V_m \cos \alpha$$

The maximum average output voltage for delay angle $\alpha = 0$,

$$V_{dm} = \frac{3\sqrt{3}}{\pi} V_m$$

In the Fig 3.23 of the output waveform above, for $\alpha = \pi/3$, the instantaneous output voltage v_o has a negative part because the current through thyristor can't be negative. The load current is always positive. Thus, with a resistive load, the instantaneous load voltage cannot be negative and the full converter behaves as a semi converter.

Chapter-4

Simulation of linear AC-DC converter

4.1 Simulation and result from the constructed circuit:

There are various way of getting AC to DC voltage converter. We can use power electronic converters such as step-down converter, step-up converter, voltage stabilizer, AC to DC converter, DC to DC converter, DC to AC converter. Here, we are doing analysis by using Single Phase Transformer with Full Bridge Rectifier.
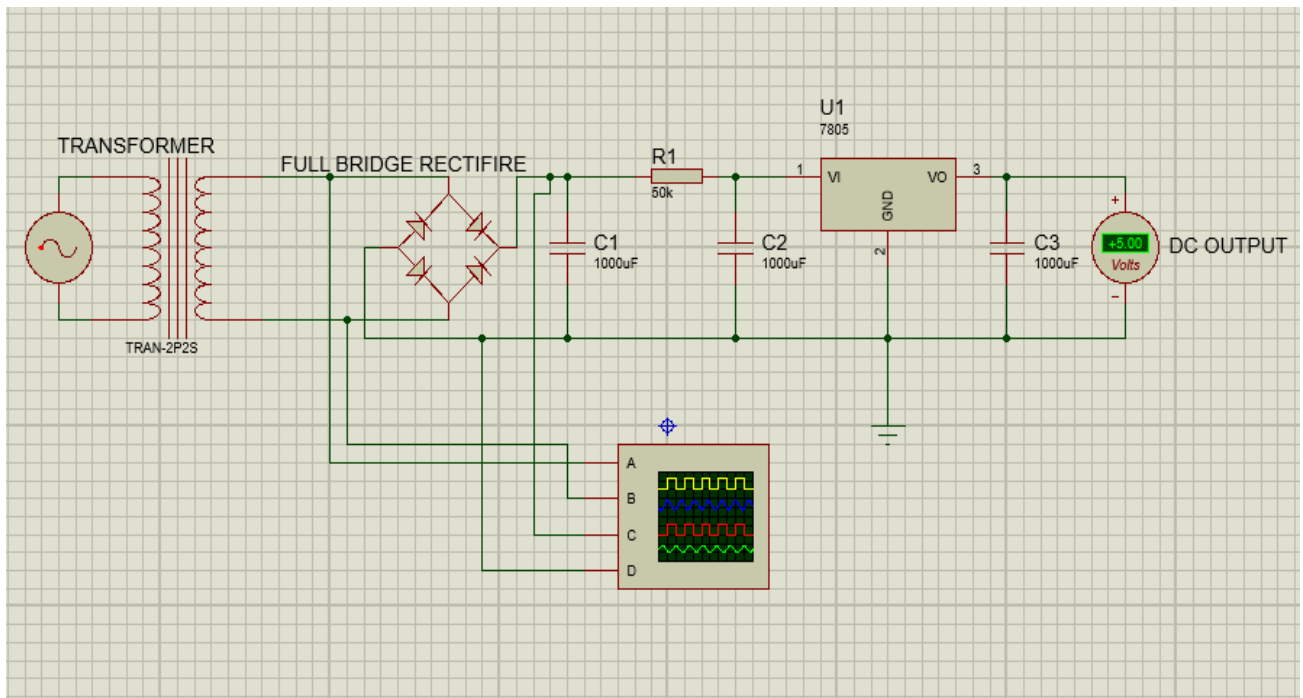

Fig 4.1: Circuit Diagram of AC voltage as input with output of Full Bridge rectifier.

From the circuit diagram shown in Fig 4.1, we give an AC source where AC voltage is given 220V and Frequency is 50Hz. Here, a transformer is attached with AC source which will transform 220v and make it a low voltage AC wave as AC voltage has positive (+Ve) and negative (-Ve) terminals. Here, after step down to a smaller voltage we need to stop polarity changes. To make electrons pass only in one direction we need diodes. Here we are using 4 diodes as a bridge so that a positive and

negative cycle will convert into a positive cycle where lower waves are lifted and make the wave as one directional. From Fig 4.2 we can see the output result of the sinusoidal wave when attached with a Full Bridge Rectifier.
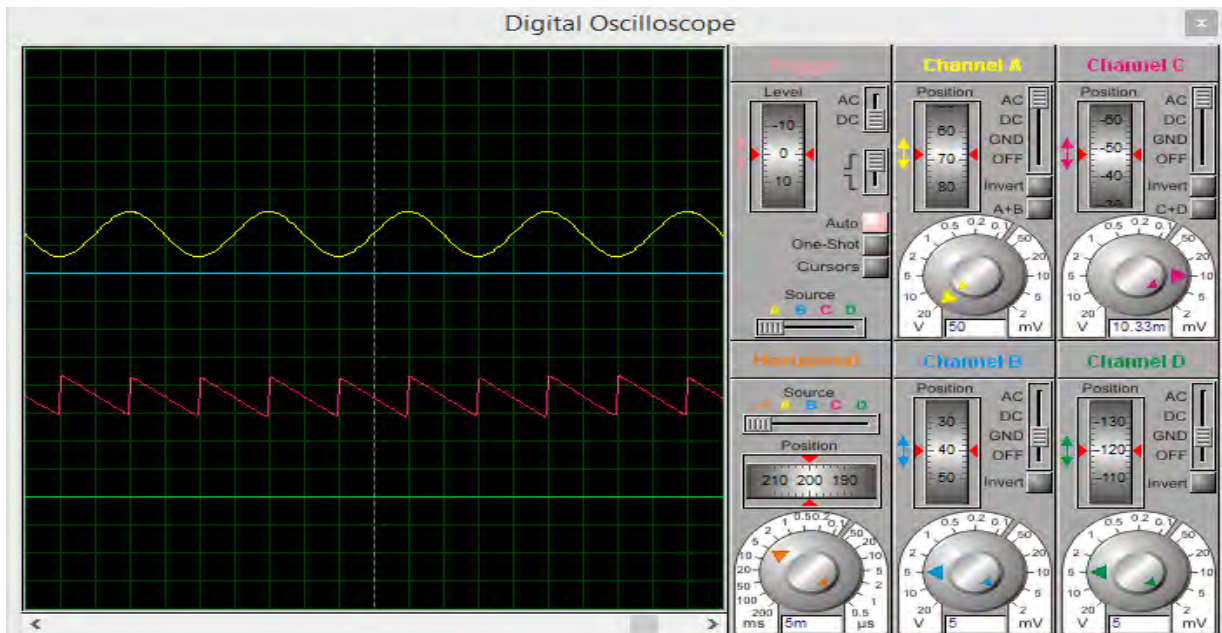

Fig 4.2: Simulation Graph of AC voltage as input with output of Full Bridge rectifier.
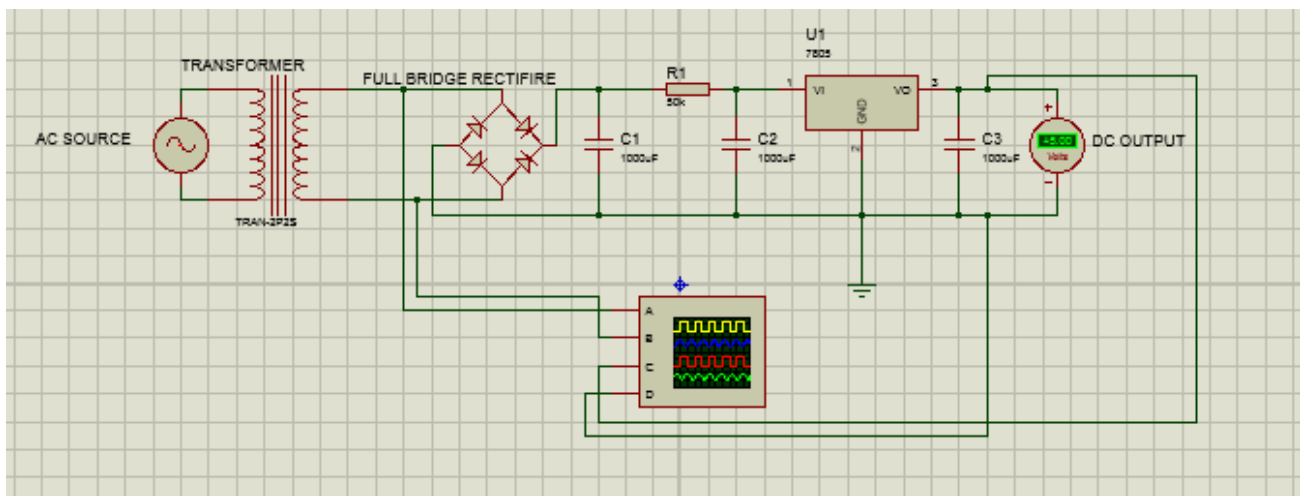
Fig 4.3: Circuit Diagram of AC voltage as input with output of DC voltage

Now, adding capacitor of higher value so that it can store charge. Here we are using Capacitors C1=1000 µF and C2=1000 µF. We can see that AC voltage come from the transformer as a sinusoidal wave, after that rectifier flips the negative half cycle into positive. Then with the help of capacitor the become smoother. Adding more capacitor we can get smoother DC voltage. From Fig 4.3. We can see the DC output which is almost straight with the help of capacitors.

From the circuit diagram, we can see the input from AC voltage coming from transformer and the output is from DC voltage source. A capacitor C3= 1000 μF is attached to store charge. Here we use oscilloscope for measuring the graph of AC input and DC output. We get output of DC voltage= +5V.
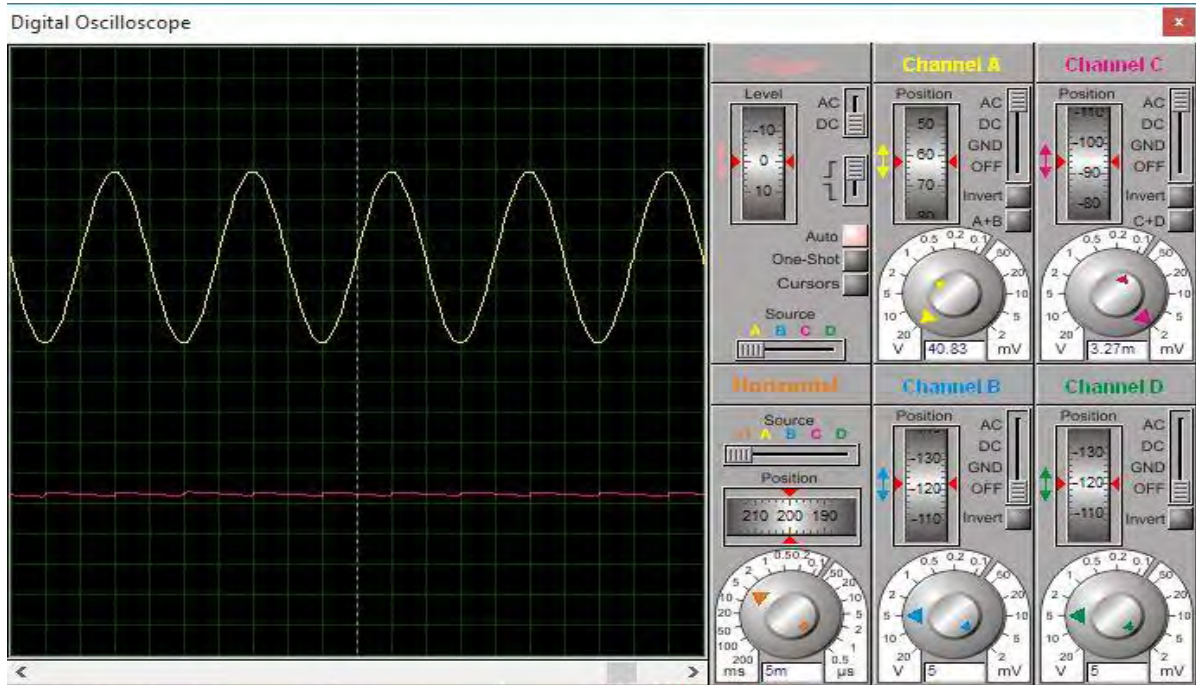

Fig 4.4: Simulation Graph of AC voltage as input with output of DC voltage.

Actually line voltage is always presented. Filter capacitor fills those gaps as they don't get discharge very fast. It's smoothly generates DC. When the first DC wave comes up capacitor get charged and wave comes to zero instantly but capacitor discharge slowly, then output line voltage is seen. As the capacitors don't get discharge very fast so capacitor fills those gaps which smoothly generates DC.

Now if we want to make it straighter then we have to add more voltage regulator. This can be done by a zener diode also. Zener diode act as same as diode but it has a condition, limitation at a specific voltage. Here we are changing ac voltage to get our desired output. We get our dc voltage 5.00V when ac voltage is 220V.

NUMBER	AC VOLTAGE	FREQUENCY	C1 (μF)	C2 μF	C3 μF	R1	DC VOLTAGE
1	120V	50HZ	1000	1000	1000	50K	3.10V
2	150V	50HZ	1000	1000	1000	50K	3.13V
3	180V	50HZ	1000	1000	1000	50K	3.18V
4	220V	50HZ	1000	1000	1000	50K	5.00V
5	250V	50HZ	1000	1000	1000	50K	5.01V
6	280V	50HZ	1000	1000	1000	50K	5.02V

Table 4.1: Practical result

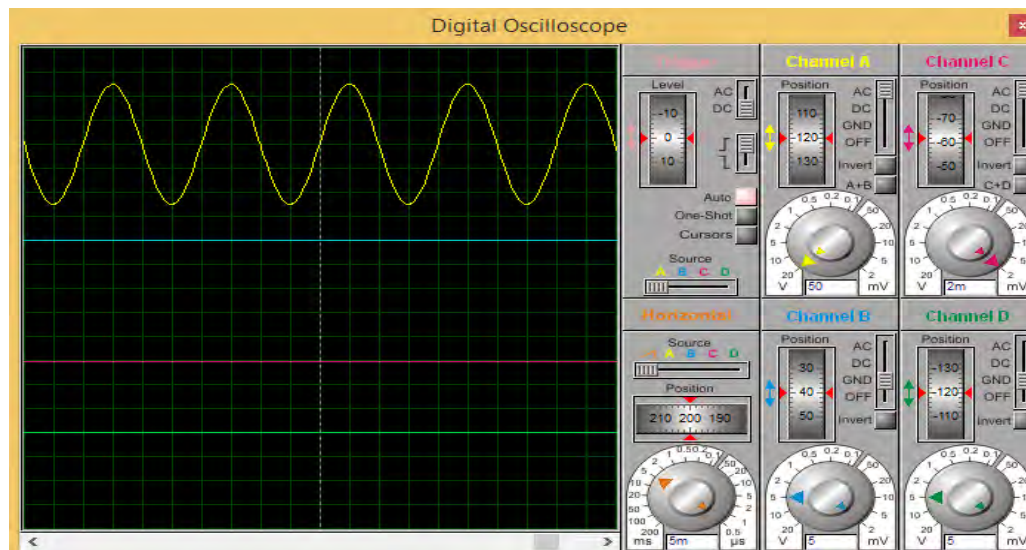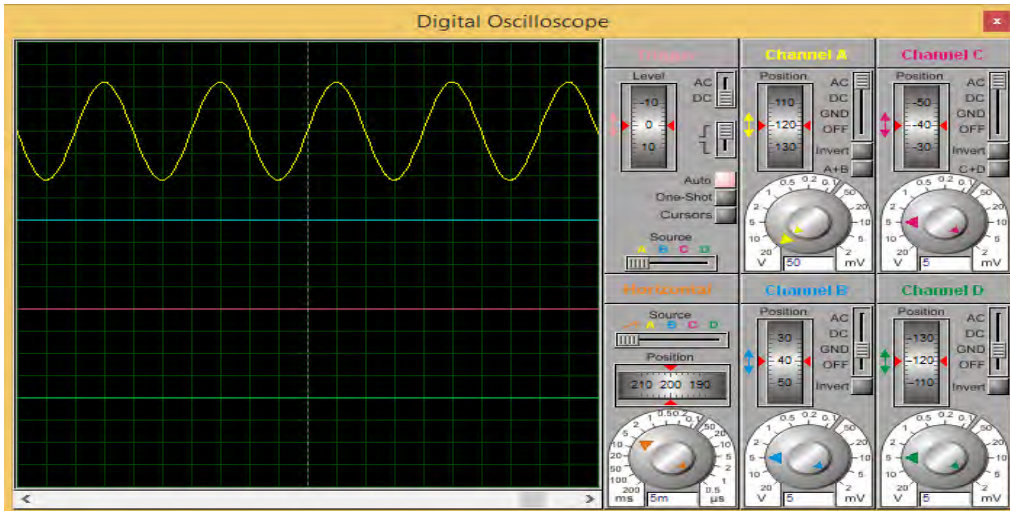## 4.2 The wave shape of the input and output voltages of the constructed circuit are shown below:
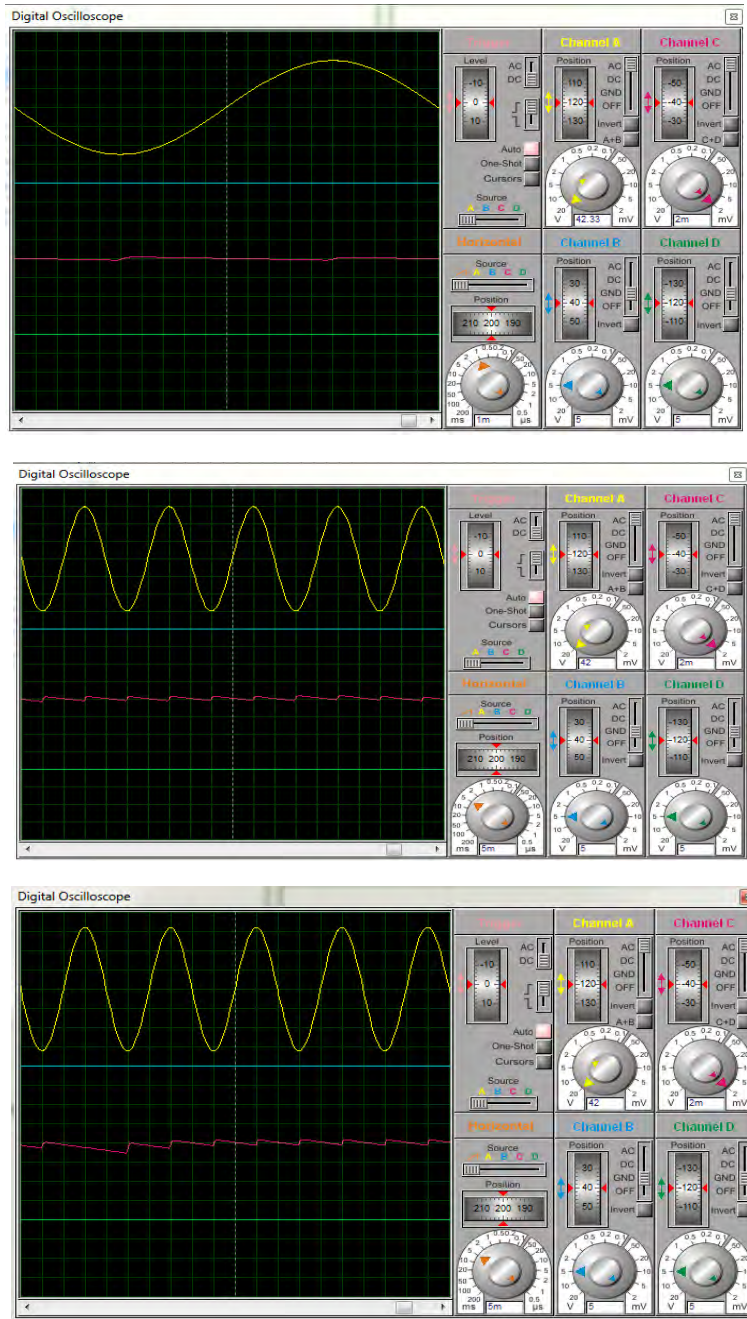
Fig 4.5: Wave shape of the constructed circuit

Chapter-05

Conclusion & Future Work

5.1 Conclusion

We have analyzed AC to DC convert by using full bridge rectifier with different combination of load and observed the DC outcomes through simulations. We also studied about different types and application of AC-DC converters, keeping our main focus on single phase with full bridge rectifier converter circuits. We gained vast knowledge about PSPICE and PROTEUS software during the project, where we carried out all our circuit construction and simulation respectively.

The main function is to have a good conversion voltage from AC to DC, for that reason where we are using full bridge rectifier instead of normal diodes attaching or Zener diode. As we know Zener diode have limitation so when it reach to that limitation it become bi-directional although it doesn't need voltage regulator but it will make bi-directional wave up to a limit. That is why we used full bridge rectifier and a voltage regulator to make a simple conversion. Beside, for better results we can use a voltage regulator chip or U0001f3a9 like 7805, 7812, 7905, 7912 to obtain a constant voltage (both positive and negative are possible).In Bangladesh the supply is 220Volts in 50Hz for households. We get 5V as DC output when we apply 220V as AC input.

5.2 Future Work

Making the most out of electrical energy is the main challenge in today's world. Whatever the obtainable power source we use should be operated in high efficiency. For future work, we can see the most efficient way of using different converters which also can be used at renewable energy sources like, solar energy, wind turbine, tidal energy etc. From this paper we can get a detailed idea of AC to DC converter and their efficiencies and implement them to get maximum output. Methods discuss here can be use and implemented in other types of converter also. Power efficiency is critical for electrical stimulators. Battery life of wearable stimulators and wireless power transmission in implanted systems are common limiting factors. Full wave bridge rectifiers are typically needed to increase the supply voltage of the output stage. Traditionally, Full wave bridge rectifiers are used with fast control to minimization of power loss of the supply voltage of the output.

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