Ministry Of Oil

Basrah Oil Training Institute

Mechanics Department

Pump and Welding Technics Sections

Second Stage

ELECTRICAL MACHINE

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Table of Contents

List of Figures

CHAPTER ONE

1 Introduction

As everyone knows that modern life depends heavily on electricity, and it is very important that people understand how simple circuits work. Simple circuitry is a good introduction to help you understand and know the circuits and the behavior of the elements in them and better.

It can be said that the circuit is a closed path of a conductive material that allows the electrons to flow continuously through it.

This chapter deals with the introduction of electrical symbols, components of the circuit, definitions of the systems used in electrical circuits and potential and potential difference.

1.1 Electrical Symbols

The aim of the electrical symbols is to represent the electrical elements and draw them within an electrical circuit to know and clarify the performance and the work of that circuit in a particular device.

However, each electrical component may have many possible representations. Electrical symbols can vary from country to country at present, but are largely internationally standardized. Some electrical symbols may become almost extinct as new technologies develop. In cases where there is more than one common electrical code, we try to provide an alternative representation.

The following figure (1.1) illustrates some electrical symbols used in electrical circuits.

مصباح نيون	Lamp - Neon	جهاز لقياس شدة التيار	Ammeter (amp meter)
محرك	Motor	مقاومة متغيرة	Potentiometer (variable resistor)
خلية كهربائية	Cell	بطارية	Battery
خلية ضوئية	Photo Cell (photo sensitive resistor)	جسر توحيد	Bridge Rectifier (Diode Bridge)
مكثف متغير	Capacitor Variable	مكثف (متسعة)	Capacitor non-polarised
ثنائي مقوم	Rectifier Semiconductor	مكثف قطبي	Capacitor polarised (see electrolytic)
ثايرستور	Rectifier Silicon Controlled (SCR) Anode Gate Cathode	دايود	Diode
أسلاك	Wires	قنطرة(جسر) تقويم	Diode Bridge (Bridge Rectifier)
مفتاح ضاغط	Switch - push (Push Button)	مولد إشارة متناوبة(مصدر)	Signal Generator
جهاز قياس الجهد	Voltmeter	فيوز حراري	Fuse
أرضي	Ground Earth	غلفانومتر	Galvanometer
ملف ذاتي	Inductor Tapped	ملف بقلب هوائي	Inductor Air Core
مصدر جهد مستمر		ملف متغير	Inductor Variable
محول بقلب هوائي	Transformer Air Core	محول بقلب حديدي	Transformer Iron Core

Figure 1.1 Electrical symbols

1.2 Electrical Circuit

The electrical circuit consists of the following basic elements:

1 - Power source: The electric power supply is equipped with electricity, and there are multiple sources of electrical energy (generators, batteries, solar cells, etc.).

2 - Electric load: It is the element that consumes electricity in the electric circuit and converts it to other energy used for different purposes such as lamps, electric heaters, motors, etc.

3. The transmission lines (electrical wires): It is connected to an electrical outlet through which wires are connected electrical circuit elements among them, and be of different types and sizes depending on the nature of the electrical circuit and its components.

4 - Switches or control systems: These elements control the delivery or cut off the power supply between the source and electric load as well as to protect the electrical circuit and give instructions to others depending on the type of circuit.

1.3 Control systems

A control device that is meant to control that device in order to do the work that you want it to do.

For example, the room lamp, if you want to be illuminated by you open its electricity switch in order to illuminate and if you want to turn it off, you press the switch again, that is, you are the controller of this switch, but if the switch works on itself, which lights up and switches off, it means you cannot control it.

1.3.1 Manual Control

This includes all types of switches include a knife switch and circuit breakers, are controlled manually.

As follows:

(a) **Knife switches**

They are in several forms, including one line, two lines and three lines, and are operated by a side arm. These types can be used on switches to connect and disconnect loaded and non-loaded electrical networks, and is also on the types:

1 - One-way Knife switches, The protection here is three fuses, thus controlling the consumer by the mechanical lever associated with the contact with the knife as in Fig. 1.2.

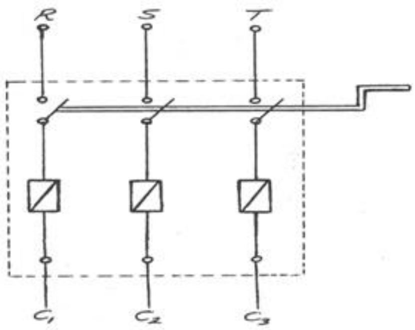


Fig. 1.2 Knife switch

1 - Two-way knife switch, which is different from the previous one because it contains contacts on both sides and the opening of the circuit by moving the fuses.

(b) Circuit Breaker

The circuit breakers are basic protective elements in the control and power circuits, through which the control and power circuits are connected and disconnected simultaneously. The connection and disconnection of these circuit breakers can be controlled by moving the supplied arm and these circuit breakers are available in the form of Single Phase and Three Phase. The entrances to the circuit breakers are always from the top and the outputs from the bottom.

Circuit breakers have power currents where ampere A circuit breakers have the following standard values:

(2,4,6,10,16,20,25,31,40,50,63,...... etc.) Amp.

Figure (1.3) shows the shape and the types of the electrical circuit breaker.

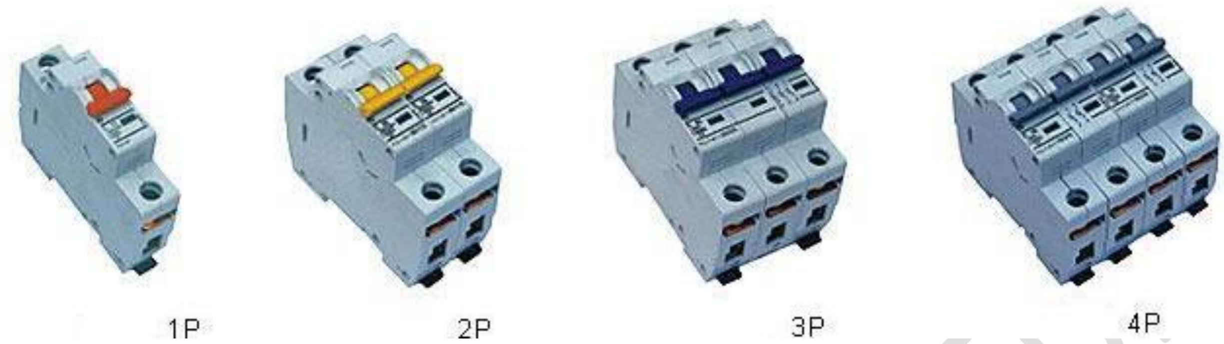


Figure (1.3) electrical circuit breaker

1.3.2 Automatic control

Is the kind of control that does not require an individual or worker to do a particular thing when you want to do something, but the system automatically performed something when something else happens, such as the washing machine.

1.4 Voltage and potential difference

Electrical voltage: The electrical voltage of a given point is the amount of work done in the unit of charge required to transfer a positive charge of one column from the infinity to that point. If the voltage describes the properties of the electric field at a given point, the unit of voltage in the global system is the voltage and the volt is the voltage of the point at which a one-joule charge is performed when a positive test load of one column is transferred from infinity to this point. The unit is:

JUL = COLOM * VOLT

Volt = Jul / Colom

The voltage difference between two points: is the amount of difference in the work done in the unit of charge required to transfer a test charge from the first point to the second point. The voltage difference points are usually referred to as positive and negative, which are of higher voltage. The voltage difference unit is also called the voltage and the voltages are measured by a device called a voltmeter.

The test charge is the charged body which can be neglected dimensions compared to the distance in which the effect of this charge is to be investigated on another object.

CHAPTER TWO

2.1 Electrical resistance

Electrical resistance is the impedance shown by the material made when the electric current passes through it. Impedance occurs in the material, whether it is the conductors or non-conductors (dielectrics) but in different degrees, which is one of the most common important electronic parts and is used to control voltages (voltage divider) and ampere (current divider). The resistance is measured in Ohm and is electrically symbolized by the character R.

2.1.1 Types of resistors Types of Electrical Resistors

Resistors are used in many ways, as in most electrical devices, especially in radios, televisions, etc. The high-power resistors are used to control the operation of electric motors and to protect electric motors at startup when the high start current is passed.

And variety in types depending on how to make, and composite materials, we review the following of some of the most important types of resistors used are:

1. Constant resistor.

2. Variable resistor.

3. Light Dependent resistor.

4. Thermal resistor.

1- Constant resistors (carbon - wire): These resistors are characterized by a constant value, where the value of resistance is fixed in the factory when manufactured and cannot be changed by the user. Their variation in use, according to their abilities to pass the current supply, the large sizes of resistors are used in high currents and smalls for low currents.

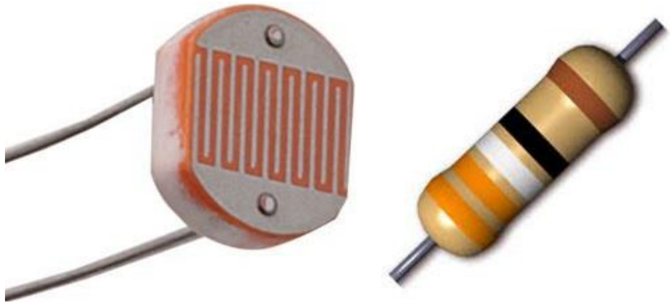
- **Carbon Resistors:** The carrier material is made of carbon and has large ohm values but small capacity.
- **Wire resistors:** The material in which the conveyor is made of wire is wrapped in the body of resistance to a certain number of coils according to the value of resistance and should be a distance between each roll, and have a small ohms, but the capacity is large.

2- Mechanical Variable resistors: A resistance can be changed mechanically or manually, its ranging between zero and maximum value, for example, when we say that the value of the resistance (10KΩ Variable resistor) means that the value of resistance ranging from zero ohm and gradually increase manually until the maximum value 10K) and can be installed on a certain value.

3. Light Dependent resistor (LDR): These resistors are made of cadmium sulfide (CDS) whose ohmic value decreases when light intensity increases, and increases in value at low light, its value is variable.

4 - Thermal resistor: The value depends on the temperature of the ocean, its value is variable. There are other types that cannot be mentioned.

Figure (2.1) shows the forms of some types of electrical resistors.



Constnt resistor

Light resistor

Variable resistors

Carbon Resistors

Figure (2.1) types of electrical resistors

Table 2.1. Multiples and Sub-multiples of Ohm

Prefix	*Its meaning*	*Abbreviation*	*Equal to*
Mega-	One million	M Ω	106 Ω
Kilo-	One thousand	k Ω	103 Ω
Centi-	One hundredth	–	–
Milli-	One thousandth	m Ω	10-3 Ω
Micro-	One millionth	µ Ω	10-6 Ω

2.1.2 Ohm's Law


George Simon

In 1825, after several practical experiments, the German scientist George Simon Oum (G. S. Ohm 1854-1789) reached a relationship between the intensity of the current passing through a conductor and the voltage differential on both ends of the conductor. The law stipulates that "the current passing through the conductor is directly proportional to the voltage difference on both ends when the temperature is constant".

Which increases the current by increasing the voltage if the resistance is constant. The mathematical expression of this law is:

$V \ \alpha \ I$,

$V = I * R$ Volt (V)

$R = V / I$ Ohm (Ω)

$I = V / R$ Ampere (A)

Where (V) is the voltage and (I) represent the current passing through resistance and (R) is the electrical resistor.

The electrical power can also be calculated from the following relationships:

[$P = V \times I$] , P (watts) = V (Volts) x I (amps)

Also:

[$P = V^2 / R$] , P (watts) = [V^2 (Volts) / R]

Also:

[$P = I^2 \times R$] , P (watts) = [I^2 (amps) x R]

The following figure (2.2) illustrates the outline of the Ohm's Law.

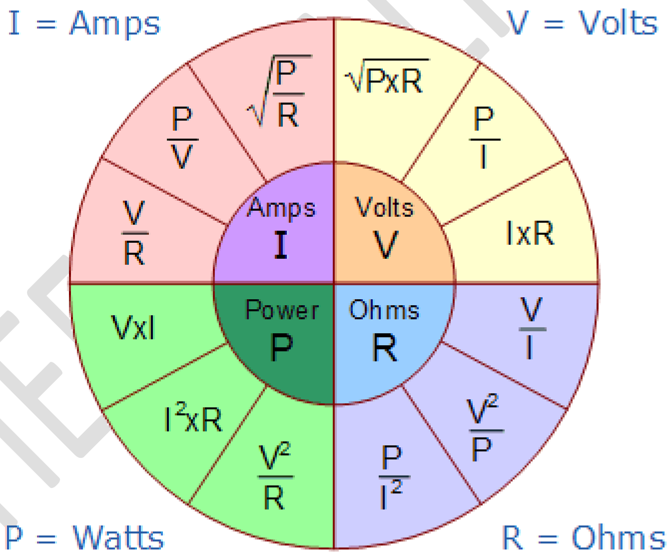


Figure (2.2) Ohm's Law

Example (2.1):

In the circuit shown in Figure (2.3), calculate the current passing through the resistor R and the power consumed in it.

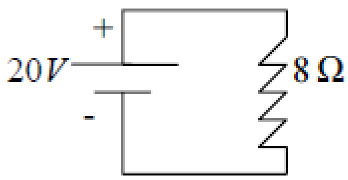


Figure (2.3)

Solution:

$$I = \frac{V}{R} = \frac{20}{8} = 2.5 \text{ A.}$$

P = V x I = 20 x 2.5 = 50 Watt.

2.1.3 Methods of connecting resistors in the Electrical circuit

There are three ways to connect the resistors which are series, parallel and both together, as they will come.

1. Serial connection:

Is the connect in which the resistors are connected to each other in the form of a series, IE the end of each resistance is connected with the beginning of the other resistance to form that the current passes through a single path.

As shown in Figure 2.4.

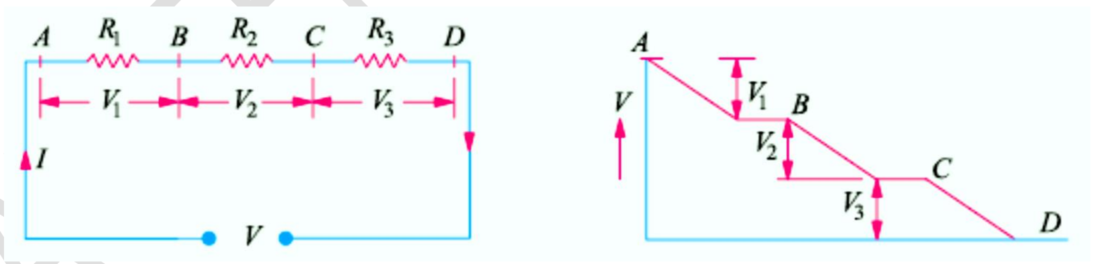


Figure 2.4 resistance in series

∴

$V = V1 + V2 + V3 = IR1 + IR2 + IR3$ —Ohm's Law

But $V = IR$

Where R is the equivalent resistance of the series combination.

$\therefore \quad IR = IR1 + IR2 + IR3 \qquad \text{or} \qquad R = R1 + R2 + R3$

As seen from above, the main characteristics of a series circuit are:
1. Same as current flows through all parts of the circuit.
2. Different resistors have their individual voltage drops.
3. Voltage drops are additive.
4. Applied voltage equals the sum of different voltage drops.
5. Resistances are additive.
6. Powers are additive.

Example (2.2):

The circuit in Figure (2.4) Find the value of the previous total resistance and voltage of each resistance if you know that the values of,

R1 = 8Ω, R2 = 8 Ω, R3 = 4 Ω, The battery is 10 V.

Solution:

$R=R_1+R_2+R_3 \quad = 8+8+4 = 20\Omega$

$$V = I \times R, \quad I = \frac{V}{R} = \frac{10}{20} = 0.5 \text{ A.}$$

$VR_1 = I \times R_1 = 0.5 \times 8 = 4$ Volt.

$VR_2 = I \times R_2 = 0.5 \times 8 = 4$ Volt.

$VR_3 = I \times R_3 = 0.5 \times 4 = 2$ Volt.

$V = VR_1 + VR_2 + VR_3 = 4+4+2 = 10$ Volt.

2. Parallel Connection:

In this connection the beginning of all the resistors is connected to each other at one point and all its ends are connected at the other point. Ie, the voltage difference between the two ends of the first resistance equals the voltage difference between the two ends of the second resistance equals the voltage difference between the ends of the third resistance and current in each resistor is different and is given by Ohm's, as shown in Figure 2.5 shows the correlation of resistance in parallel.

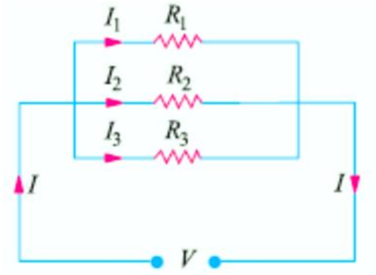


Figure 2.5 resistance in parallel

$I = I_1 + I_2 + I_3 = \dfrac{V}{R1} + \dfrac{V}{R2} + \dfrac{V}{R3}$

Now, $I = \dfrac{V}{R}$, Where V is the applied voltage.

R = equivalent resistance of the parallel combination.

$$\frac{V}{R} = \frac{V}{R1} + \frac{V}{R2} + \frac{V}{R3} \quad \text{or} \quad \frac{1}{R} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}$$

The main characteristics of a parallel circuit are:

1. Same voltage acts across all parts of the circuit
2. Different resistors have their individual current.
3. Branch currents are additive.
4. Conductances are additive.
5. Powers are additive.

Example (2.3):

Three resistors connected in parallel as in Figure 2.5 with their values (3 ohm, 2 ohm, 6 ohm) respectively. Calculate the total equivalent resistance and the current of each resistance if the source voltage is 10 volts.

Solution:

R1= 3Ω ,

R2= 2Ω ,

R3= 6Ω

$$\frac{1}{R} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}$$

$$= \frac{1}{3} + \frac{1}{2} + \frac{1}{6}$$

R = 1 Ω

$V = V_{R_1} = V_{R_2} = V_{R_3} = 10$ Volt

$V = I \times R_T$, $I = \frac{V}{R} = \frac{10}{1} = 10$ A.

Calculation the Currents in the Resistors :

$$I_1 = \frac{V}{R1} = \frac{10}{3} = 3.33 \text{ A.}$$

$$I_2 = \frac{V}{R2} = \frac{10}{2} = 5 \text{ A.}$$

$$I_3 = \frac{V}{R3} = \frac{10}{6} = 1.66 \text{ A.}$$

3 . Compound Connection:
In which a set of resistors, two or more is connected in parallel and in series with the other resistors, in which the two groups are combined series and parallel connections.

Example:
Calculate the total current of the circuit in the following figure, if you know that the values of resistors and voltages are as follows:

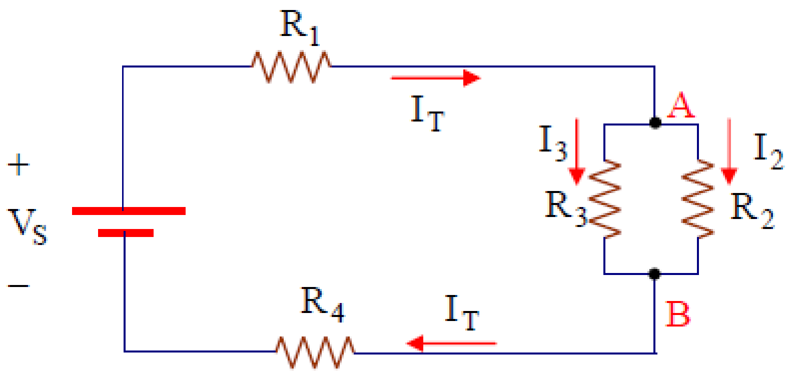
R1= 50 Ω ,

R2= 200 Ω ,

R3= 200 Ω ,

R4= 50 Ω

Vs = 50 Volt.



Solution:

$$RT = R1 + \frac{R2*R3}{R2+R3} + R4$$

$$= 50 + \frac{200*200}{200+200} + 50$$

$= 50 + 100 + 50$

$RT = 200\ \Omega$

$I_T = \frac{Vt}{RT} = \frac{50}{200} = 0.25$ A.

2.2 Electrical current

Electrical current: A stream of electrons that pass through a specific section in a conductor wire over a period of time.

According to the international system of units, the current strength is measured in amperes, while the electrical current is measured by the ammeter device, and symbolized by the symbol (I).

Electrical conductors that contain free motion charges during the material are called electrons. Metals such as silver and copper come into the forefront of materials containing these free electrons, which are characterized by their random movement in all directions. It is known that electrons are responsible for the formation of electrical currents in metal conductors.

The electrical current has several effects, including:

1 - thermal effect: When the electricity flow in a conductor, it gives a thermal effect in this conductor, where the temperature increases in it. The temperature directly proportional to the current intensity that passing through the conductor as well as with its resistance. The benefit of this property used in furnaces and heaters, etc.

2. Magnetic effect: When an electric current enters a conductor, a magnetic field is produced around the conductor. This property is used in many devices such as electric bells, electric motors and electric transformers, etc.

3. Chemical effect: When an electric current enters a chemical solution, it is ionized and analyzed. This process is called electrolysis. This feature is used in the manufacture of batteries, electroplating, electro-printing, etc.

4. Light effect: When an electric current enters a special impedance conductor (tungsten wire), it is heated and then glows to a white light as in the lamps.

The electric current is divided into two types:

1. Current Current (D.C).

2. Alternating current (A.C).

2.3 DC Current (Characteristics and Sources)

DC is a flow of electrons passing through an enclosed circuit, which can be obtained from batteries and DC generators. Its properties have constant value and direction.

It has electrical symbol (I) and the unit of measurement Amps (A). The current is measured by a device called ameter where it is connected in series with the circuit. As shown in Figure 2.6.

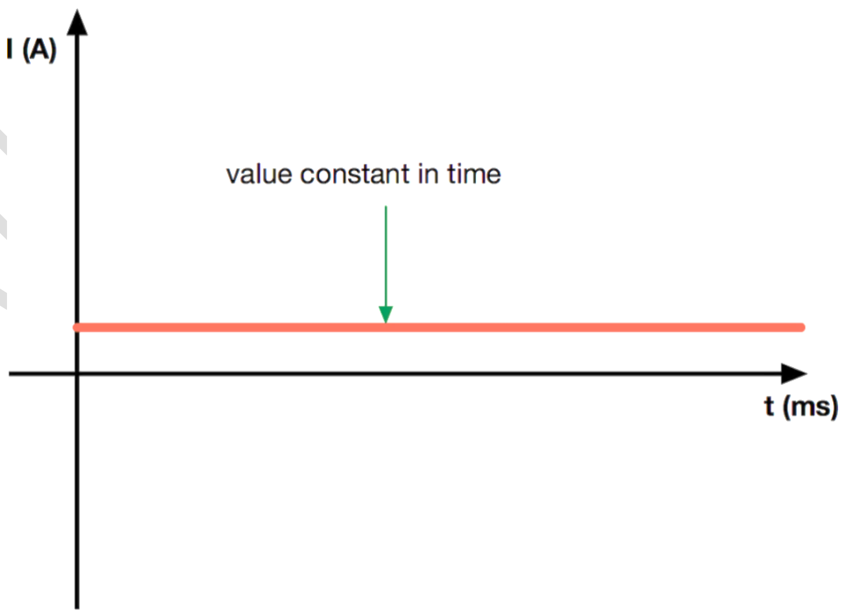
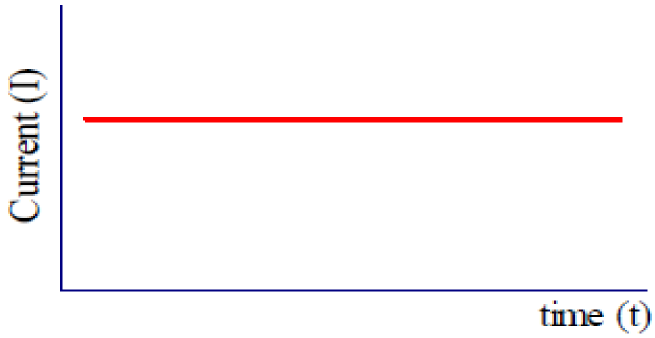
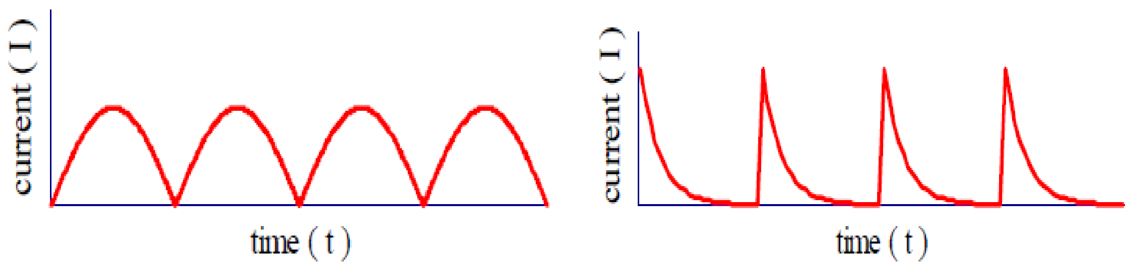


Figure 2.6 D.C. properties

DC currents differ from one form to another, depending on the mode of generation IE (source), so the output current production of the battery is a **Pure DC Current** as shown in the previous figure either the output current production from converting AC to DC is a **pulse current**. It is a variable, but its direction is constant as shown in Figure 2.7.



Pure DC Current



Pulse current

Figure 2.7 DC waveforms

2.4 Alternate current (characteristics and sources)

The sinusoidal alternating current is a stream of electrons passing through the electric conductor in closed circuit, which periodically reflects its direction. It is the variable value and direction and oscillates go and back 50 or 60 times per second according to the electrical system used. The magnitude of this current and its direction are changing with the time (t) so that it passes through each cycle with the same changes as the previous cycle and produces a sine function as shown in Fig. 2.8, can only be generated according to the law of Faraday by an electrical generator.

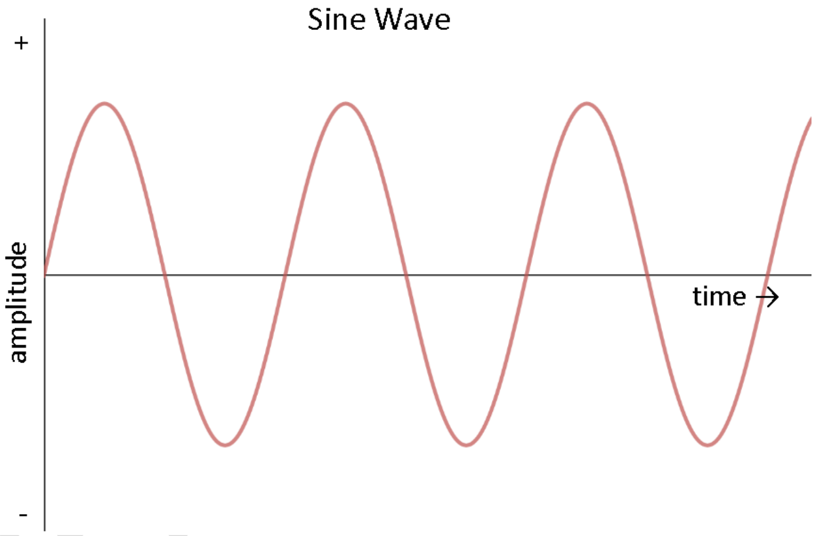


Fig. 2.8 The sinusoidal alternating current

2.5 Sine wave generation and angular frequency

AC changing with the time can be described by a sine equation on the image:

$$i(t) = i_{max} * Sin(wt)$$

Where,

i_{max}: is the maximum value of an AC,

t: is the time and

w: is the angular frequency.

The angular frequency (W) has a (1 / s) unit such as frequency f, which is also measured in hertz (Hz) unit (1 /s). Figure 2.9 shows the changing of the current, voltage and power over the time.

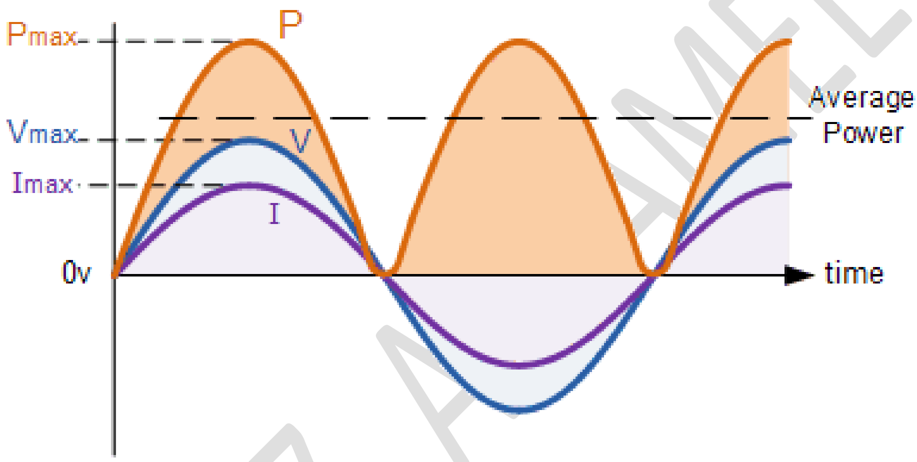


Figure 2.9 Changing of the current, voltage and power over the time

The cycle is a state change that repeats itself at equal intervals. This period is called cycle time and the cycle time T can be calculated by the inverted frequency f.

$$T = \frac{1}{f}$$

In most countries of the world, the frequency of alternating current that used in homes has a cycle time of,

$$T = \frac{1}{f} = \frac{1}{50\ Hz} = \frac{1}{50}\ \text{s} = 20\ \text{ms}$$

Figure 2.10 shows how to Generate sine wave.

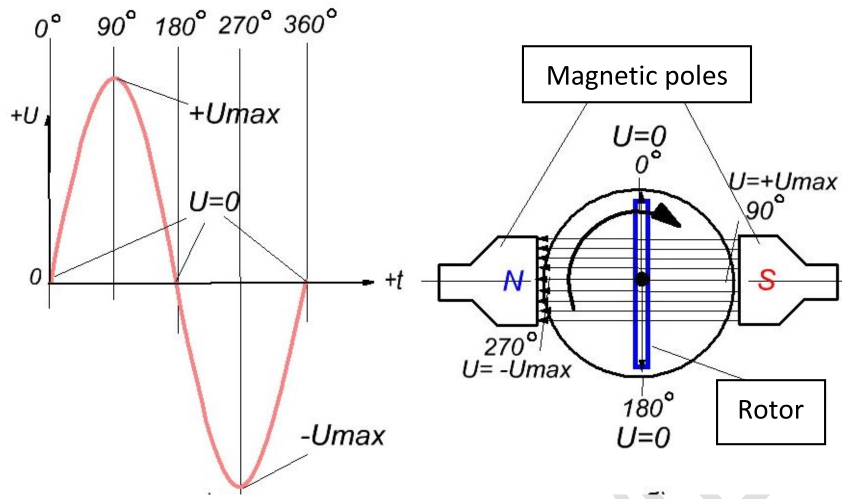


Figure 2.10 Generation sine wave

Angular frequency ω: is the amount of angle required to form a wave per one second and can be calculated from the following relationship.

$$W = 2 * \pi F \qquad \text{rad / s}$$

Its unit is the radius to the second.

When the alternating current passes through the pure ohmic resistance load, the voltage and current waves are will be in the same phase as in the following figure 2.11 and the phase difference angle is zero ($\Theta = 0$) and by applying Ohm’s law we can calculate the voltage.

$$V(t)= V_m \sin(\omega t) = i * R$$

$$i = I_m \sin(\omega t)$$

When an alternating current passes through a pure inductive load (Inductive Reactance), if the current wave is,

$i = I_m \sin(\omega t)$

The voltage wave will be

$V(t) = V_m * \sin(\omega t + 90)$

Note that the wave current is lagging behind the voltages at an angle of (ϴ - 90º) (Lagging) as shown in Figure 2.12.

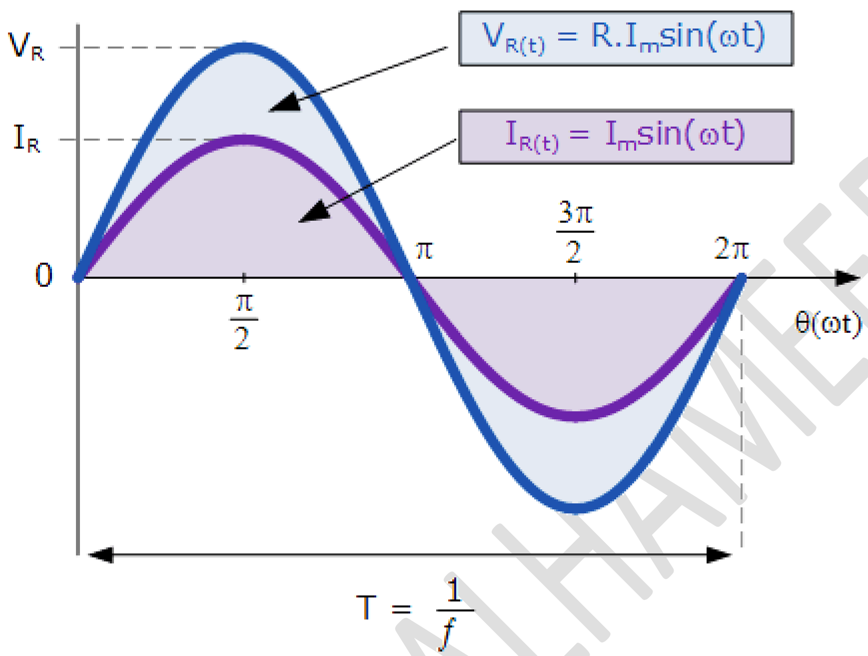


Figure 2.11 Voltage and current waves of pure resistance load

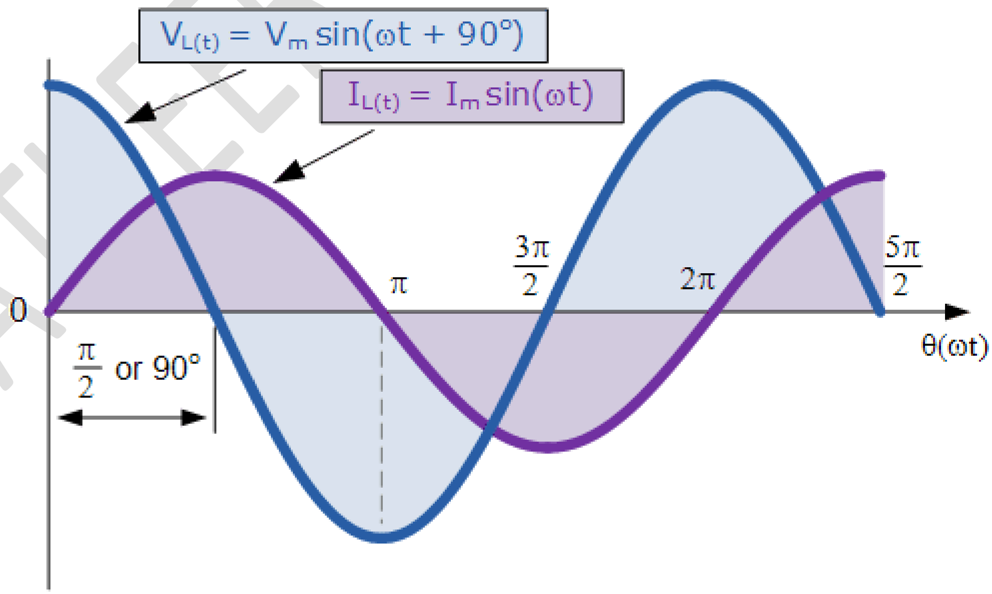


Figure 2.12 Voltage and current waves of pure inductive load

The value of the inductive reactance can be calculated from the following law,

$$X_L = \omega L = 2\,\pi\,f\,L \quad (\Omega)$$

While when an alternating current passes in a pure capacitive load (Capacitive Reactance), if the voltage wave is,

$$V\,(t) = V_m * \sin\,(\omega t)$$

The current wave will be

$$I\,(t) = I_m \sin\,(\omega t + 90^o)$$

Note that the current wave is leading the voltages at an angle of (ϴ +90º) as shown in Figure 2.13. The value of the capacitive reactance can be calculated from the following law,

$$XC = \frac{1}{wc} = \frac{1}{2\,\pi\,f\,C} \qquad (\Omega)$$

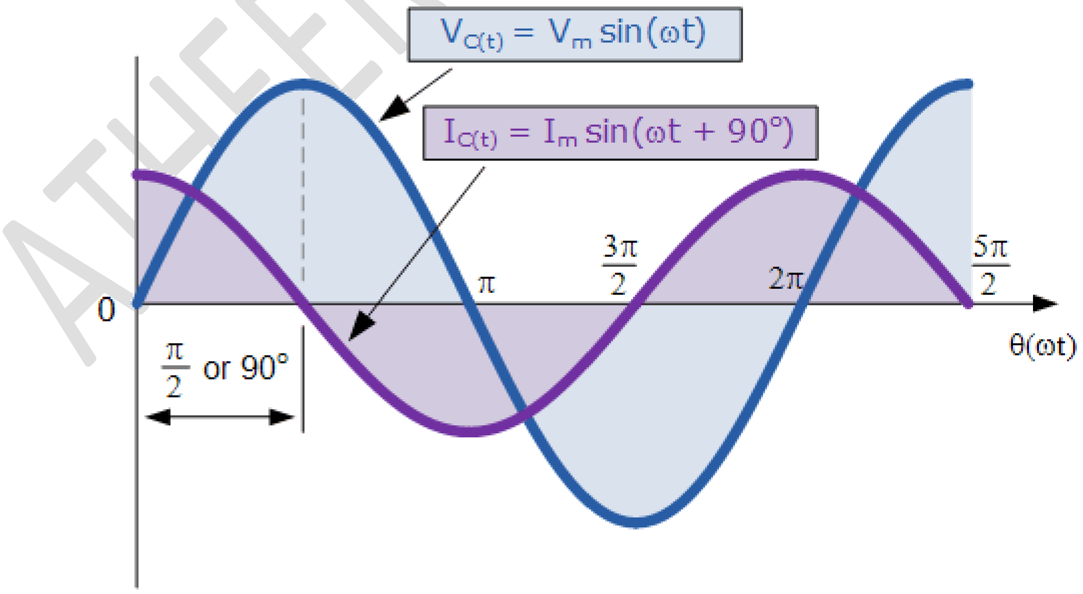


Figure 2.13 Voltage and current waves of pure capacitive load

It should be noted that the voltage and current in an alternating current circuits are directional quantities of magnitude and angle so that the vectors can be dealing with it mathematically and in all processes. Therefore, there is a phase difference angle separating the voltage and the current is(ϕ). So the current vector can be analyzed into two vectors ,vertical and horizontal as shown in Figure 2.14.

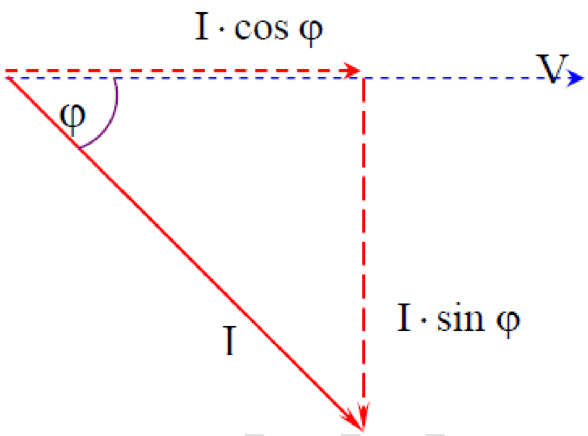


Figure 2.14 current vectors

The horizontal vector is called the **Active Power** vector and calculated by,

$$P = V * I * \cos\phi$$

The vertical vector is called Reactive Power, which is calculated by,

$$Q = V * I * \sin\phi$$

This triangle is called the power triangle, and ($\cos\phi$) is called Power Factor (PF).

Some waveforms of alternating current,

It is often the alternating current used in the sinusoidal wave, but there are several forms that can be shaped, including sawtooth, square, and others. The most important here are some of the concepts of the periodic waves as shown in Figure 2.15.

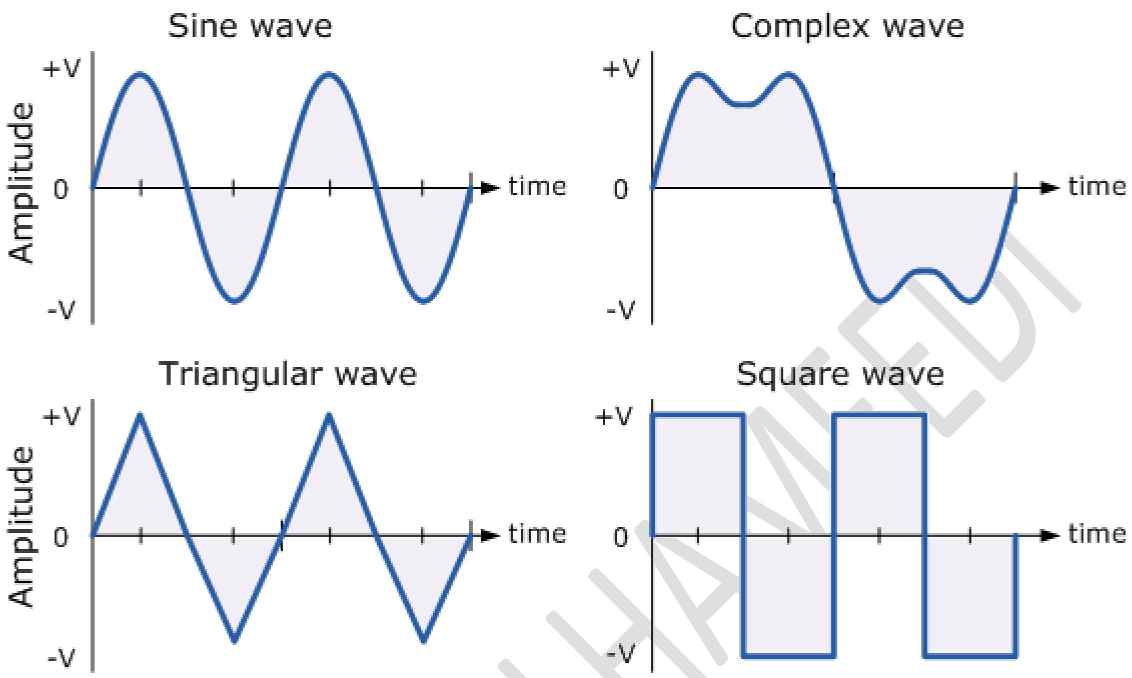


Figure 2.15 periodic waves

The Period (T): is the length of time (measured in seconds) that the wave takes to recreate itself. For square waves, it is called **pulse width**.

Cycle: it is a time taken by the wave to complete a whole pattern starting from zero, then the positive path and the negative path and ending by returning to the zero on the line basis. So the cycle of the wave contains the two parts, positive part and negative part. The time taken by the wave to complete one cycle is called (Periodic Time) and symbolized by the symbol T.

The relationship between periodic and wave frequency is,

$$\text{Frequency}, (f) = \frac{1}{\text{Periodic Time}} = \frac{1}{T} \text{ Hertz}$$

Or

$$\text{Periodic Time}, (T) = \frac{1}{\text{Frequency}} = \frac{1}{F} \text{ Second}$$

Duty Cycle: it is the percentage to describe the amount of work time (on time) of the digital wave when (signal is high) to the time of the wave T, as shown in Figure 2.16.

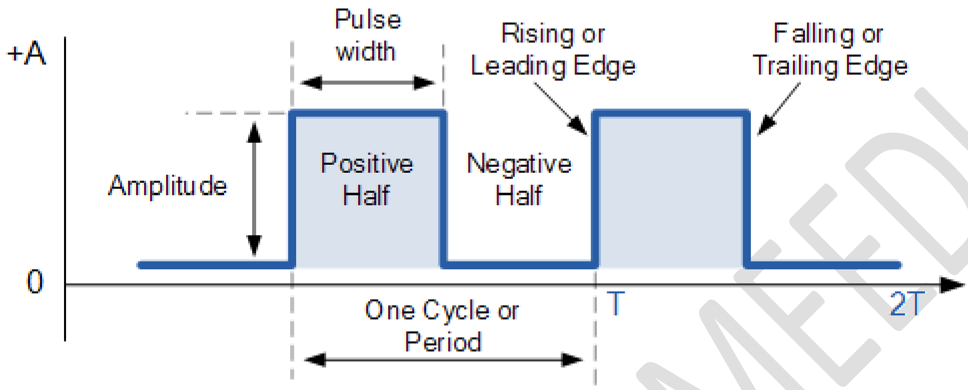


Figure 2.16 square wave

The duty cycle of the wave can be calculated by dividing the radial width by the time the wave takes to complete one cycle.

$$D = \frac{PW}{T} \times 100\%$$

Where,

- **D is the duty cycle**,
- **PW is the pulse width (pulse on or active time)**
- **T is the total period of the signal.**

If the time of the digital wave takes half time and the off time takes the other half, we say that the digital wave has a duty cycle (50%) and is like an ideal square wave. If the ratio is above 50%, the time on the digital wave takes longer than the low time or the off time and Conversely if the duty cycle is less than 50%. The following figure 2.17 illustrates these three cases.

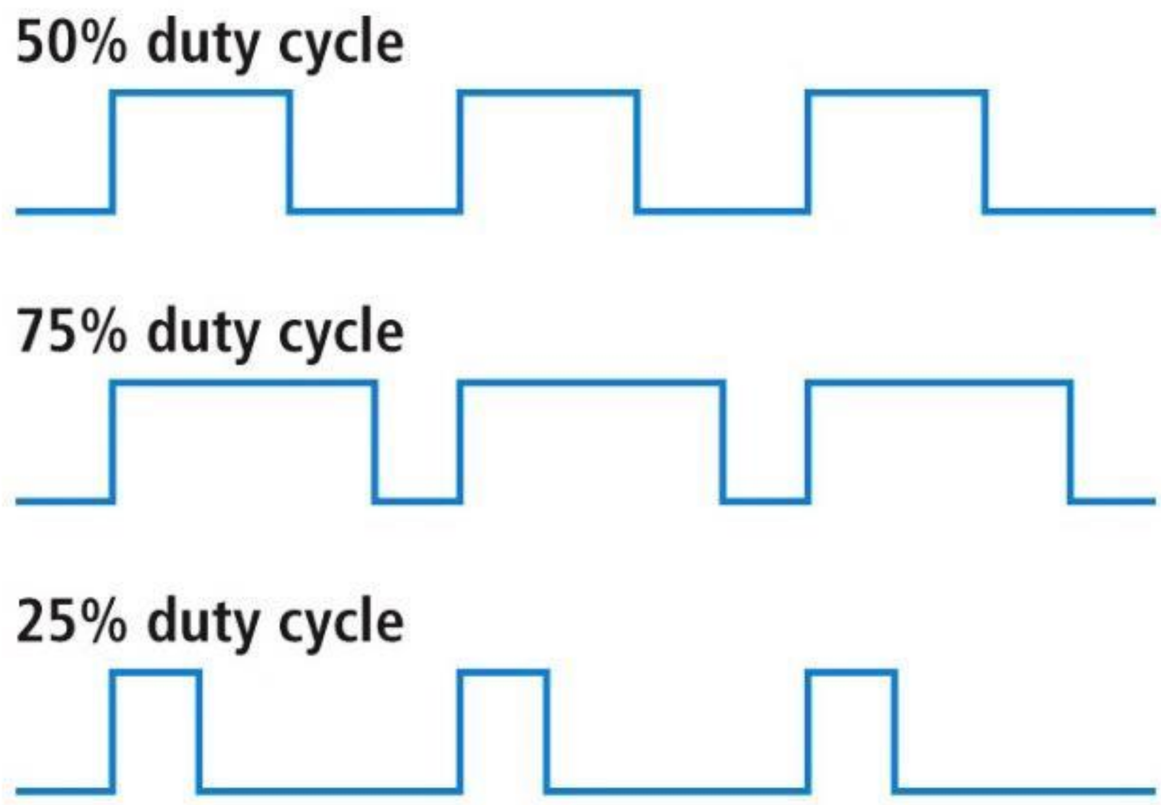


Figure 2.17 Duty Cycle

Duty Cycle of a Welder

The duty cycle of an arc welder is based on a working period of 10 minutes. For example, if a welder is operated for 2 minutes in a period of 10 minutes, then its percentage duty cycle is (2/10) × 100 = 20 percent. Conversely, a 10 percent duty cycle would mean that the welder would be operated for 10 percent of 10 minutes, i.e. for one minute only in a period of 10 minutes.

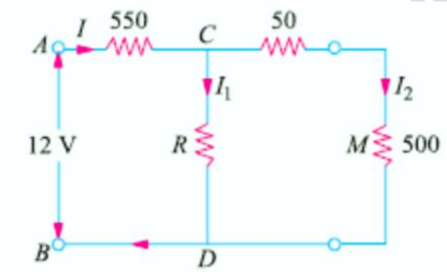
Usually, values of maximum amperage and voltage are indicated along with the duty cycle. It is advisable to adhere to these values. Suppose a welding machine has a maximum amperage of 300A and voltage of 50 V for a duty cycle of 60 percent. If this machine is operated at higher settings and for periods longer than 6 minutes, then its internal insulation will deteriorate and cause its early failure.

Questions

Q1 / Calculate the amount of electric current and power consumed per kilowatt hour due to the lighting of eight lamps each capacity (100 W) for five hours of AC 220 V source.

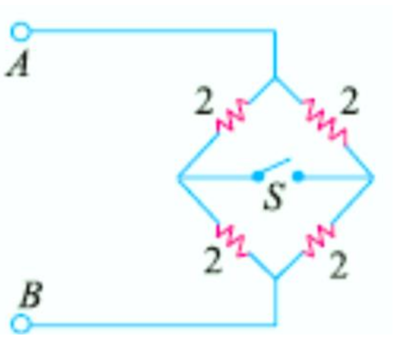
Q2 / 500 Watt electric heater, calculate the amount of electric current and the electrical power consumed as a result of the operation of this heater two hours of AC 220V source.

Q3/ *What is the value of the unknown resistor R in Figure follow if the voltage drop across the 500 Ω resistor is 2.5 volts ? All resistances are in ohm.*



Q4/ In the circuit of Figure follow, find the resistance between terminals *A* and *B* when the switch is

(a) Open and (*b*) closed. Why are the two values equal?



CHAPTER THREE

3.1 Magnetic Field

It was possible to discover natural stones and rocks that have the ability to attract some minerals such as iron and cobalt in the area called (magnesia) was named magnet which natural forms were subsequently formed artificially, as used Navigators compass where they discovered that when suspended magnet comments free, one of the parties heading towards the north earth geographical is called the (North Pole) because it has been attracted to the south earth geographical as well as to the other end of the magnet called the South Pole because, it has been attracted to the north earth geographical.

3.1.1 Properties of the Magnet

1- It has two northern and southern poles when it hangs a free comment. It heads north and south.

2. Magnetic attraction is concentrated in its poles and is lower in other regions.

3 - Different poles in the types are attracting and the similar types are repulsioning.

4 - If the magnet cut from any area in it, will consist for it two poles and cannot have one pole.

3.1.2 Magnetic field lines

The field can be practically planned using iron filings, sprayed over a light piece of paper placed over one or more magnets, where the iron filings molecules are placed in straight lines and others are curved around the poles and spaced away, called magnetic field lines.

3.2 Magnetic Field for a Wire Carrying Electrical Current

The scientist Orsted studied the magnetic fields that products from the electric current by placing a straight wire through which a constant electric current passes over a magnetic needle based on a pointed tooth. In fact, the needle deviates from its natural position and becomes perpendicular to the wire. Indicating that the electrical current will generate around the wire a magnetic field in the form of a circlure lines whose there center are the wire itself. Figure 3.1 shows the deviation of the compass needle to the wire of the electrical current.

The magnetic field can be defined as: the force that affect on electrical charge moving generated by currents or (movement). This means generating the magnetic field along the wire carrying the current.

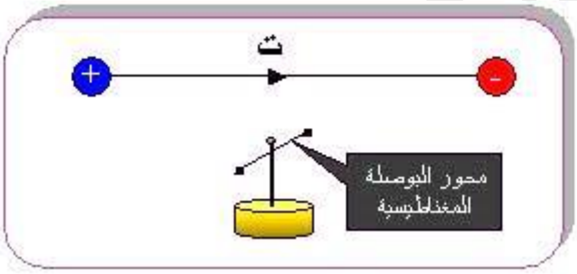


Figure 3.1 deviation of the compass needle to the wire

Characteristics of magnetic field lines

1. Imaginary lines are concentric circles centered in the center of the wire.

2. The magnetic flux density depends on the amount of the current passing through the wire.

3- The direction of the magnetic flux lines depends on the direction of the current passing through the wire.

3.3 Electromagnetic field Intensity

The amount of the force of the magnetic field that affect at a point within it during passing the current in wire called (magnetic field intensity). Or Electric intensity at a point may be defined as (equal to the lines of force passing normally, through a unit cross-section at that point).

The number of lines of magnetic field passing through an area of space is called the magnetic flux and its measured by a unit called Weber.The number of magnetic fluxes that pass vertically through the unit of space is called the magnetic flux density (B). The magnetic flux density is measured in wb / m2, called Tesla T.

3.4 Electromagnetic induction

Is to generate voltages through an electrical conductor located in a variable magnetic field or by motion the conductor and moving it through a fixed magnetic field.

Electromagnetic induction is the basis for the work of generators, induction motors, transformers, and many other electrical machines.

The Faraday Act of Electromagnetic Induction states that the electromotive force in the conductive wire is generated when the wire cuts the magnetic field lines.

It can be expressed by the following law,

$$E = -\frac{d\emptyset}{dt}$$

Where E is the electromotive force in volts,

$\emptyset$ is the magnetic flux in Weber.

In the case of a wire roll consisting of N winding, Faraday's law states that,

$$E = -N\ \frac{d\emptyset}{dt}$$

N is the number of roll wire.

The law of Lenz also gives the direction of the electric force as follows,

Changing the magnetic flow inside a roll from an electrical conductor leads to an induced voltage until the current generates a magnetic field that is directed to counteract the magnetic flow.

Thus, Lenz's law explains the existence of a negative sign in the previous equation.

The following figure 3.2 shows how to generate an electromotive force and the deviation of the galvanometer index.

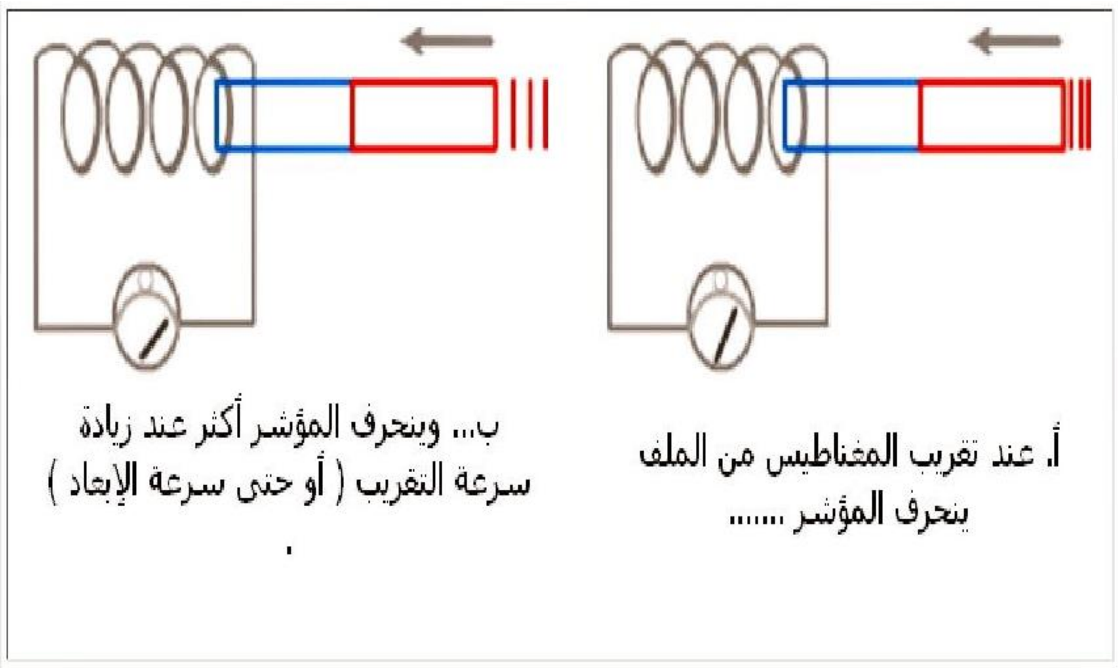


Figure 3.2 generates an electromotive force and the deviation of the galvanometer index

CHAPTER FOUR

4.1 Electrical machinery

It is a device that transfers or converts energy from one form to another and from one image to another and depends on the principle of its work on the phenomenon of electromagnetic induction. There are two types of electrical machines,

A - Rotary electrical machines: These machines contain moving parts within the installation, such as motors and generators.

B- Static electrical machines: These machines do not contain moving parts within the installation such as electrical transformers.

The rotary electric machines are divided into:

1. Motors: such as induction motors, synchronous motors etc.

2. Generators: such as diesel generators, steam, water, nuclear generators and others.

While the electric machines are divided according to the current type into two parts: DC machines and AC machines as shown in Figure 4.1.

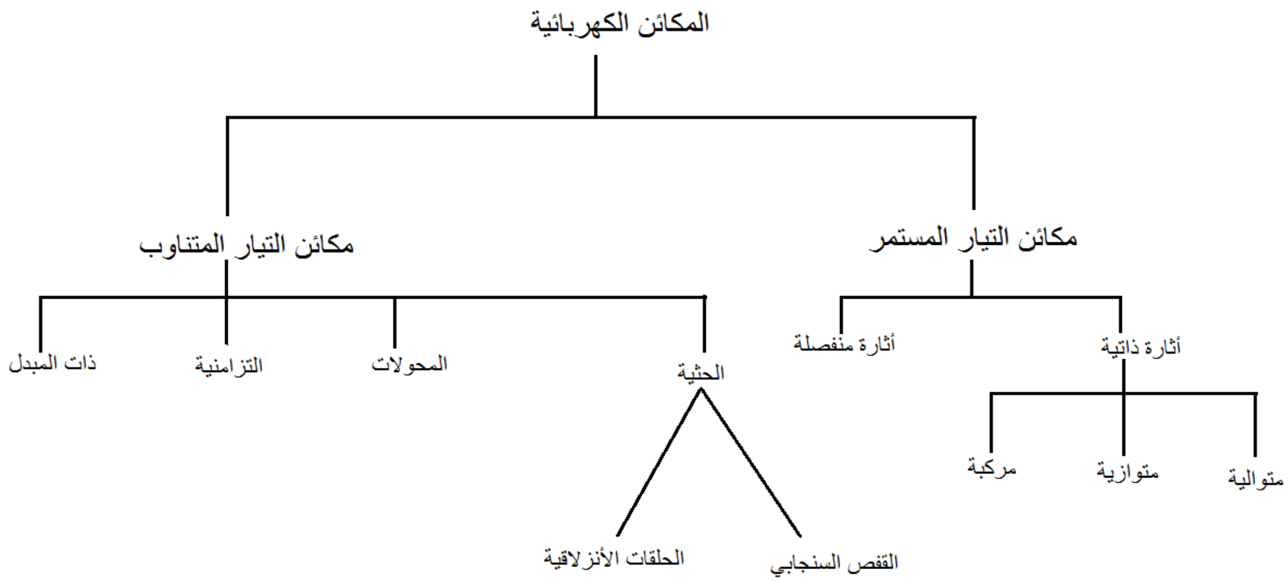


Figure 4.1 electric machine types

Electrical alternating machines are divided according to the number of phases for:

1- Single-phase machines: Machines that operate on a single-phase source has limited powers and are used for household and general purposes. 60% of the world's machinery production constitute from it.

2-Two phase machines: Machines designed from two separated coils and used for special purposes only as auxiliary engines in control systems.

3-Multi-phase machines: It is designed for several coils such as three-phase machines, which designed from three coils so that feed from a three-phase source machine. These machines have highly efficient.

4.2 DC. Machines

A DC machine is a reflective machine that is used as a generator or as a motor. Therefore, their construction is similar.

Construction of DC machines:

DC motors are constructed from the following parts, as shown in Figure 4.2.

1. Yoke:

It is an external structure made of the cast steel where it is preferable to the cast iron because its large magnetic permeability factor, which makes the size of the structure smaller than that of iron, as it is characterized by its mechanical properties. The utility of the structure is:

(A) Carrying the magnetic poles, which it is fixed by bolts.

(B) Complement the magnetic circuit of the poles.

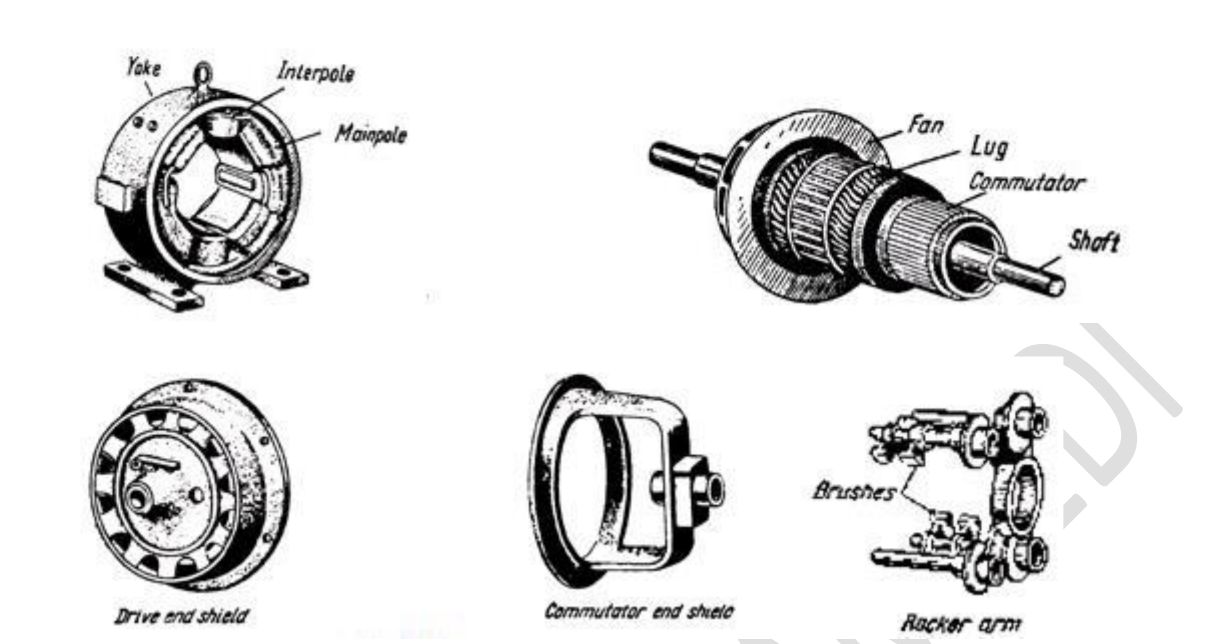


Figure 4.2 Construction of DC machine

2-Main poles:

They are electro-magnetic poles constructed from the iron heart, which is made from the steel of the generator and in the form of isolated chips to reduce the circulating currents and the magnetic obstruction generated by the current of the armature, and then combine and connect with each other and then ends pole shoes to facilitate the passage and regularity of the magnetic field during the air gap. Then wrapped with well-isolated copper coils and then connect these coils in a series with each other so that they give magnetic space continuously, IE, north, south, and so on.

3- Rotor: consists of

(A) Armature: made of chips from the generator's steel in the form of circuits isolated from each other and from the axis of rotation (to reduce the circulating currents and magnetic obstruction). The outer consist of ducts for placement of copper conductors after isolation to generate electricity in the coils as a result of armature movement in the magnetic field of the main poles. The output current is alternating current. Figure 4.3 shows the chips of the armature.

(B) Commutator: It consists of a copper cylinder made of copper segments isolated from itself and of the axis of rotation and these segments relate to the ends of the armature coils. The benefit of a commutator is to unify the alternating current produced in the armature coils to a direct current in the generator while, inverting the current direction of the armature coils in the motor.

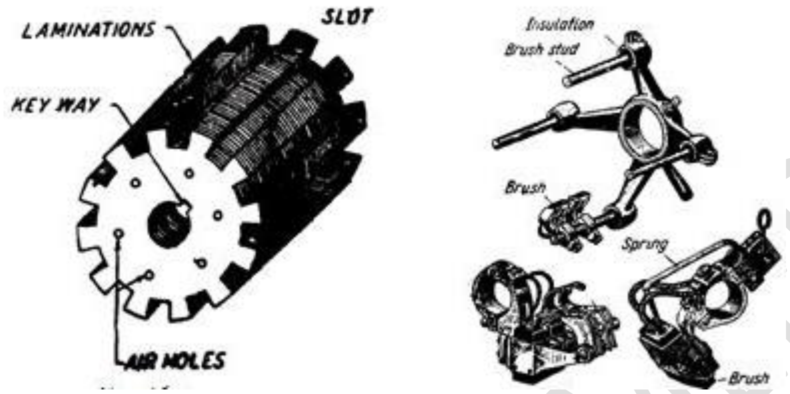


Figure 4.3 Chips of the armature

(C) Brushes & Bearings:

Brushes It is made from compressed carbon or red copper fixed on commutator by house brushes installed on the holder brushes to be always in contact with the commutator and therefore need to be pushed around by the spring. The brushes contact with the commutator must be a good contact to avoid the spark that a result of not Good communication with the armature. The benefit of carbon brushes is to connect the output current from the armature and the commutator to the external circuit (the load circuit) and their number is paired.

3.4 DC. Generators

The generator does not create energy, but converts mechanical energy into electrical energy, so every generator is run by a turbine, a diesel engine, or any machine that produces mechanical energy. For example, the dynamo generator runs from the same engine that drives the vehicle.

Engineers usually refer to a mechanical machine that runs the generator to the main engine. In order to obtain additional electrical power from the generator, the main engine needs to exert additional mechanical energy. For example, if the primary engine is a steam turbine, the steam flow in the turbine needs to be increased to obtain more electricity.

4.3.1 Theory of electric generator work and voltage generation

An electrical generator is a machine which converts mechanical energy (or power) into electrical energy (or power). For example, the dynamo generator runs from the same engine that drives the vehicle. The energy conversion is based on the principle of the production of dynamic (or emotionally) induced (e.m.f.) as seen from Figure 4.4, whenever a conductor cuts magnetic flux, dynamically induced (e.m.f.) is produced in it according to Faraday's Laws of Electromagnetic Induction. This (e.m.f.) causes a current to flow if the conductor circuit is closed.

Hence, two basic essential parts of an electrical generator are

(i) A magnetic field and
(ii) A conductor or conductors which can so move as to cut the flux. Where it consists of four main parts: -

Figure 4.4 shows simple direct current generator with two permanent magnetic poles moving between them. A rectangular coil (armature) connected to the ends of a copper cylinder represents the commutator. The current collects from the commutator by two brushes.

We get a constant current not stable, to get constant current with a constant value, we must increase the number of coils as well as the number of commutator pieces.

($E = B\ L\ V \sin \Theta$)

E: e.m.f.

B: Magnetic flux density.

L: wire length.

V: The speed of the movement of the conductor within the magnetic field.

Ө: The angle between the connector and the magnetic field lines.

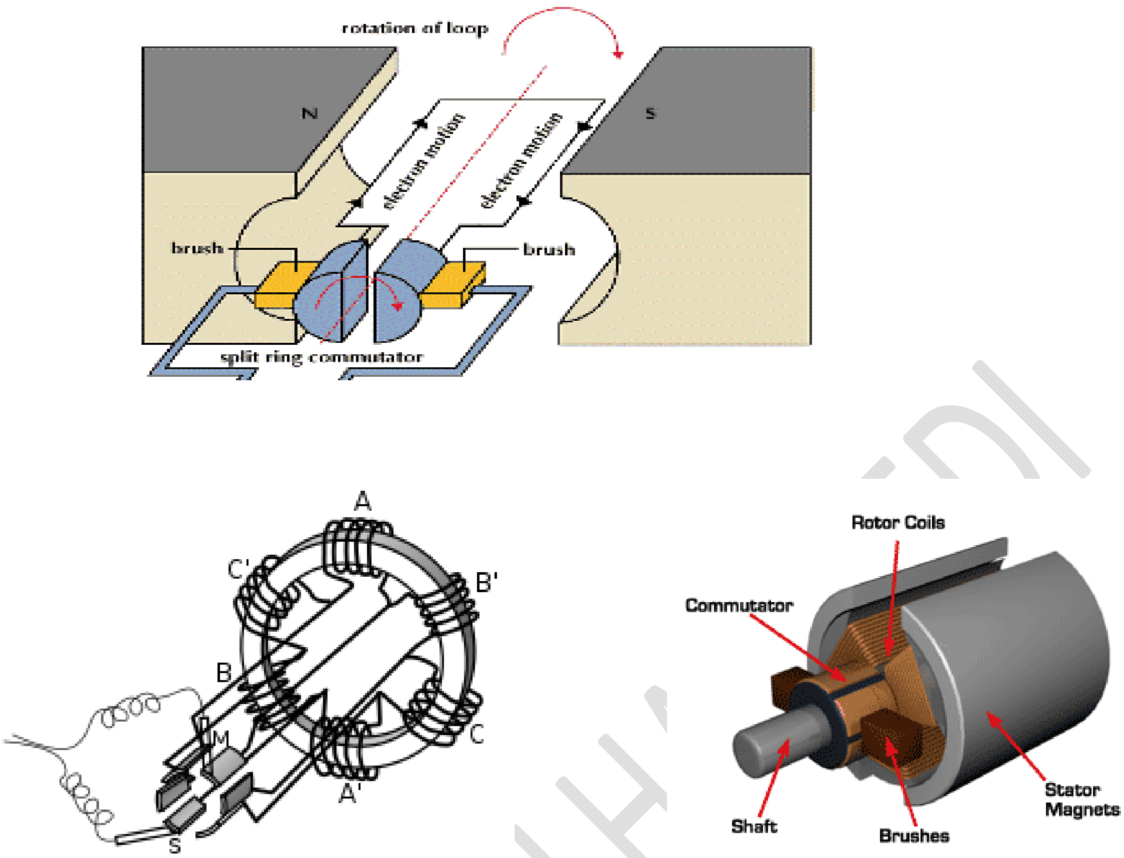


Figure 4.4 Simple Direct Current Generator

Types of DC generators in terms of feeding main poles can be divided into:

1-Permanent magnet generator (Magneto):

The poles of this generator in the form of shoe brushes made of dry steel, which keeps its magnet for a long time and this type is used in small generators as in cars and bicycles.

2-Generator with electro-magnetic poles: It is divided into two types,

(A) Separately Excited Generator:

The poles of this generator are fed from an external source such as a battery or other DC generator. This method is used in the school labs and in feeding the AC generators in the electrical stations where the control of the armature voltage is smooth.

(B) Self Excited Generator:

The poles of this generator are fed by the same direct current that provided by the armature, condition, there is permanent magnetism residual in the poles.

There are three types of self-excited generators named according to the manner in which their field coils (or windings) are connected to the armature.
1 - Connect the coils of the main poles in series with the armature coils and in this case called a DC series generator.

2 - Connect the coils of poles in parallel with the armature coils and in this case called a DC shunt generator.

3- Part of coils of the main poles are connected in series with the armature coils and the other part in parallel with it in this case called a compound generator.

4.3.2 Conditions for generating voltage

1- A small amount of magnetism remaining in the poles.

2- The direction of rotation and armature coil connection must be correct.

3- The excitation should be in the case of no load (open circuit), the field resistance less than the critical resistance (can be found from the curve of the open circuit).

4- The excitation should be in the case of load (closed circuit), the field resistance is the least, (can be found from the curve of the inner characteristic).

4.3.3 Types of DC excited Generators

1- Series Wound Generator:

The field windings are joined in series with the armature conductors (Figure 4.5). As they carry full load current, they consist of relatively few turns of thick wire or Strips. Such generators are rarely used except for special purposes, *i.e.* as boosters etc.

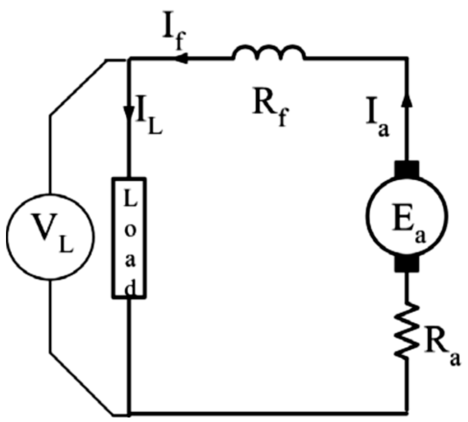


Figure 4.5 series wound generator

Ea = VL + Ia (Ra + Rse) 1

Ia = Ise = IL 2

Rse = Rf: is a series field resistance

Ia: Alarmeger current

Ea: E.M.F Of the generator

2- Shunt Wound Generator:

In this case,the field windings are connected across or in parallel with the armature conductors and have the full voltage of the generator applied across them (Figure 4.6).

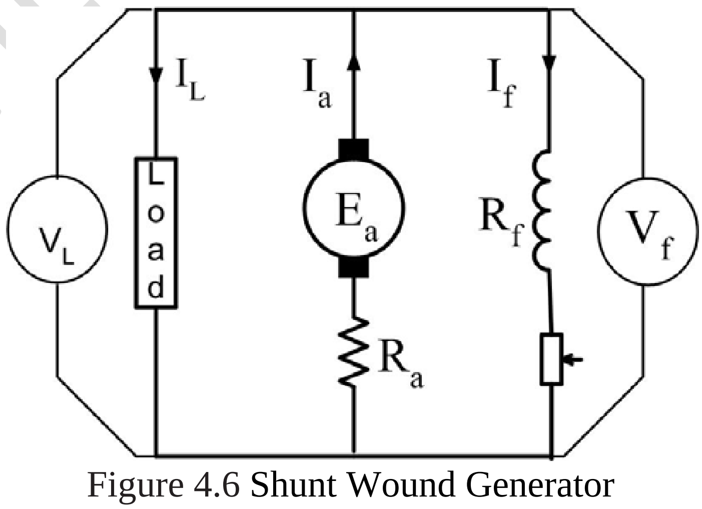


Figure 4.6 Shunt Wound Generator

$E_a = V_L + I_a R_a$ ………1

$V_L = V_f(V_{sh}) = I_{sh} \; R_{sh}$ ……….2 ,

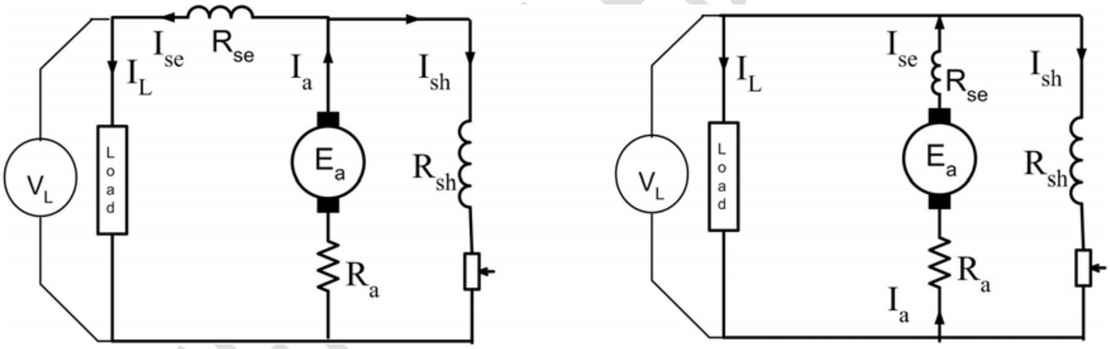
$I_a = I_L + I_{sh}$…………..3

Where, $I_{sh} = I_f$ and $R_{sh} = R_f$

R_{sh}: is a shunt field resistance

3- Compound Wound Generator

It is a combination of a few series and a few shunt windings and can be either short-shunt or long-shunt as shown in Figure 4.7. In a compound generator, the shunt field is stronger than the series field. When series field aids the shunt field, generator is said to be commutatively-compounded. On the other hand, if a series field opposes the shunt field, the generator is said to be differentially compounded.



Short-shunt Long-shunt

Figure 4.7 Compound wound generator

<u>Short-shunt</u>

$E_a = V_L + I_{se} R_{se} + I_a R_a$ …….1

$I_a = I_{se} + I_{sh}$ ……..2 ,

Where

$I_{se} = I_L$

<u>Long-shunt</u>

$E_a = V_L + I_a (R_a + R_{se})$ ………1

$I_a = I_{sh} + I_L$……….2 ,

Where,

$I_{se} = I_a$

Example: A short-shunt compound generator delivers a load current of 80 A at 250 V, and has armature,series-field and shunt-field resistances of 0.05 Ω, 0.03 Ω and 100 Ω respectively. Calculate the induced e.m.f. and the armature current. Allow 1V per brush for contact drop.

Solution:

$I_L = 80$ A

$V_L = 250$ V.

$I_{se} = I_L = 80$ A

$I_a = I_{se} + I_{sh}$

$E_a = V_L + I_{se} R_{se} + I_a R_a$

$V_{sh} = I_{sh} R_{sh} = V_{se} + V_L = I_{se} R_{se} + 250 = 80 * 0.03 + 250 = 252.4$ Volt.

$I_{sh} = V_{sh} / R_{sh} = 252.4 / 100 = 2.524$ A.

$I_a = I_{se} + I_{sh} = 80 + 2.524 = 82.524$ A.

Brush drop = 2 . 1 = 2 V

$E_a = V_L + I_{se} R_{se} +$ Brush drop $+ I_a R_a = 250 + 80 * 0.03 + 2 + 82.524 * 0.05$

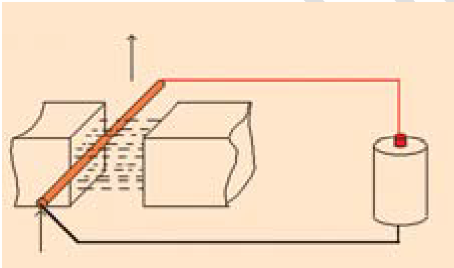
$= 258.5262$ Volt.

4.4 DC Motors

4.4.1 DC Motor Principle of operation

An Electric motor is a machine which converts electric energy into mechanical energy. Its action is based on the principle that when a current-carrying conductor is placed in a magnetic field, it experiences a mechanical force whose direction is given by Fleming's Left-hand Rule and whose magnitude is given by,

$F = B\,I\,l$ Newton,
Where,
F: Force
B: Magnetic flux density
L: Wire length
I: Condector Current


Principle of Motor

Also, when feeding the motor, the conductor as a result of cutting the magnetic flux lines, induction EMF will generate on the ends of the conductor and can be calculated from the following equation:

$E_a = (2P / 2a)\, Z_a\, (N / 60)\, \phi$

Or

$E_a = V_L - I_a R_a$

4.4.2 Types of DC Motors

Constructional there is no basic difference between a d.c. generator and a d.c. motor. In fact, the same d.c. machine can be used interchangeably as a generator or as a motor. D.C. motors are also like generators, shunt-wound or series-wound or compound-wound.

1- Series Wound Motor:

The field windings are joined in series with the armature conductors (Figure 4.8). This type of motor is characterized by the fact that the number of field windings is small and the area of the segment is large. This type of motor is used in cases where the initial torque is high, as in (cranes, locomotives) where the speed increases when reducing the load.

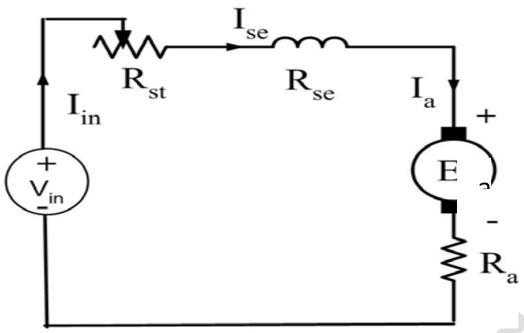


Figure 4.8 Series Wound Motor

$E_a=V_{in} - I_a(R_a+R_{se})$ ………….1 ,

Where ,

$I_a=I_{in}=I_{se}$ ………..2

2-Shunt Wound Motor:

The field windings are connected across or in parallel with the armature conductors and have the full voltage of the generator applied across them (Figure 4.9). The number of field windings of This type of motor is large and the area of the segment is small.

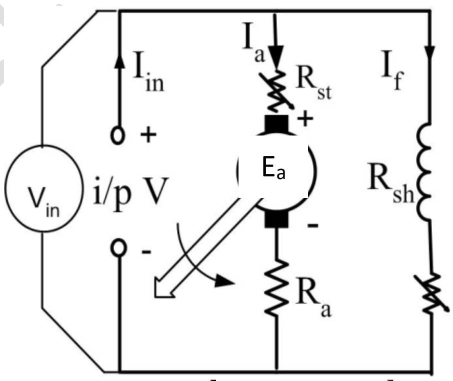


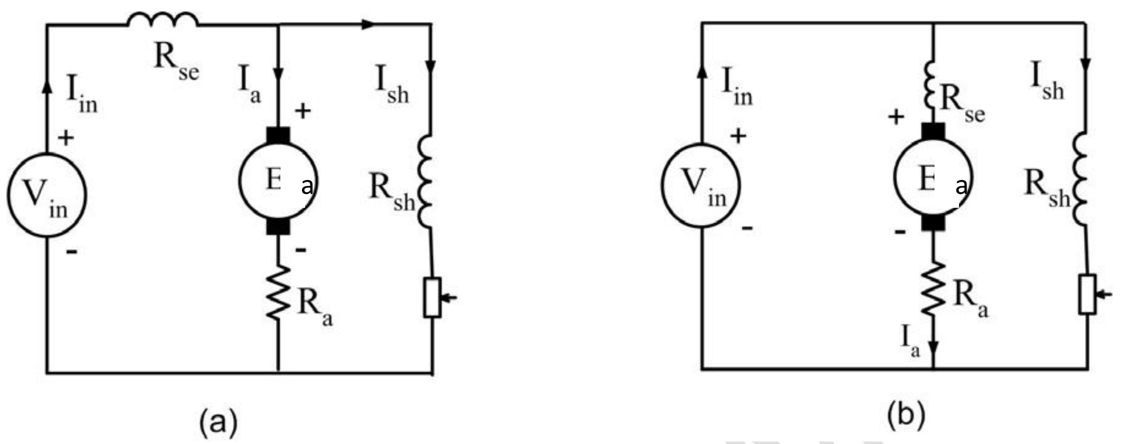
Figure 4.9 Shunt Wound Motor

$E_a = V_{in} - I_a R_a$ ………….1

$I_{in} = I_a + I_{sh} (I_f)$ ………….. 2

3-Compound Wound Motor:

It is a combination of a few series and a few shunt windings and can be either short-shunt or long-shunt as shown in Figure 4.10.



Short shunt Long shunt

Figure 4.10 Compound Wound Motor

<u>Short shunt</u>

$E_a = V_{in} - I_a R_a - I_{se} R_{se}$ ……….. 1

$V_{sh} = I_{sh} R_{sh} = V_{in} - I_{se} R_{se}$ ………… 2 , Where

$I_{in} = I_{se} = I_a + I_{sh}$

<u>Long shunt</u>

$E_a = V_{in} - I_a (R_a + R_{se})$ ………… 1

$I_{in} = I_a + I_{sh}$ ………….. 2 , Where

$V_{sh} = I_{sh} R_{sh} = V_{in}$

To calculate the efficiency of the generator or motor as follows:

$\eta\% = (Pout / Pin) x 100\%$

Summary of Motors Applications

Type of motor	*Characteristics*	*Applications*
Shunt	Approximately constant speed Adjustable speed Medium starting torque (Up To 1.5 F.L. Torque)	For driving constant speed line shafting Lathes, Centrifugal pumps Machine tools Blowers and fans Reciprocating pumps
Series	Variable speed Adjustable varying speed High Starting torque	For traction work, i.e. Electric locomotives Rapid transit systems Trolley, cars, etc. Cranes and hoists Conveyors
Cumulative Compound	Variable speed, Adjustable varying speed, High starting torque	For intermittent high torque loads For shears and punches Elevators Conveyors Heavy planers Heavy planers Rolling mills; Ice machines; Printing Presses; Air compressors

4.5 Electrical transformers

A transformer is a static (or stationary) piece of apparatus by means of which electric power in one circuit is transformed into electrical power of the same frequency in another circuit. It can raise or lower the voltage in a circuit, but with a corresponding decrease or increase in current. The physical basis of a transformer is **mutual induction** between two circuits linked by a common magnetic flux. In its simplest form, it consists of two inductive coils which are electrically separated but magnetically linked through a path of low reluctance as shown in Figure 4.11. The two coils possess high mutual inductance. If one coil is connected to a source of alternating voltage, an alternating flux is set up in the laminated core, most of which are linked with the other coil in which it produces mutually induced (e.m.f.) (according to Faraday's Laws of Electromagnetic Induction (***e = MdI/dt***). If the second coil circuit is closed, a current flows in it and so electric energy is transferred (entirely magnetically) from the first coil to the second coil. The first coil, in which electric energy is fed from the a.c. supply mains, is called the ***primary*** winding and the other from which energy is drawn out, is called ***secondary*** winding.

A transformer that contains two coils is called a double-wound transformer, while transformer that contains three or more coils is called a multi-wound. In relation to the current phase type, the transformers are classified into single phase, three phase Multi-phase.

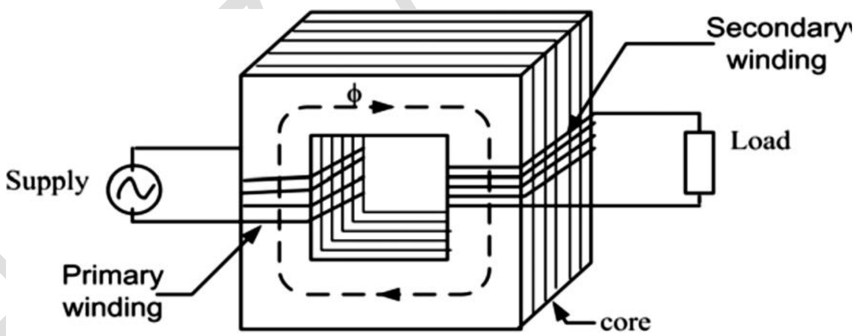


Figure 4.11 Electrical Transformer

Single Phase Transformer

Construction:

The simple elements of a transformer consist of two coils having mutual inductance and a laminated steel core. The two coils are insulated from each other and the steel core. Other necessary parts are: some suitable container for assembling core and windings; a suitable medium for insulating the core and its windings from its container; suitable bushings (either of porcelain, oil-filled or capacitor-type) for insulating and bringing out the terminals of windings from the tank.

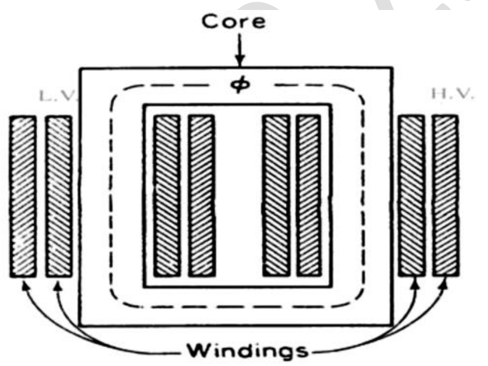
1- Iron Core: the core is constructed of transformer sheet steel laminations assembled to provide a continuous magnetic path with a minimum of air-gap included. The steel used is of high silicon content, sometimes heat treated to produce a high permeability and a low hysteresis loss at the usual operating flux densities. The eddy current loss is minimised by laminating the core, the laminations being insulated from each other by a light coat of core-plate varnish or by an oxide layer on the surface. The thickness of laminations varies from 0.35 mm for a frequency of 50 Hz to 0.5 mm for a frequency of 25 Hz. The core laminations (in the form of strips) are joined as shown in Figure 4.11.

2- Windings: The transformer windings can be classified into two categories:

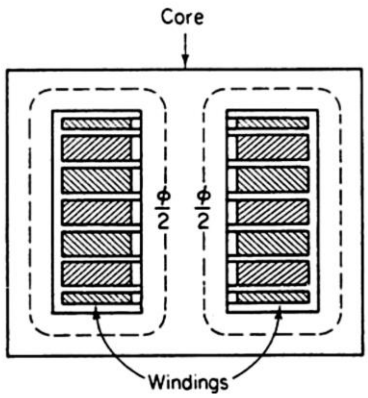
A-Concentric Winding: It is made in the form of cylinders and used in central core transformer.

B-Sandwich Winding: It is made in the form of Sandwich.

These two types are shown in Figure 4.12. Figure 4-12a shows a single phase transformer with concentric Winding. This type is commonly used, while Figure 4.12b shows a single-phase shield-shaped transformer containing sandwich Winding.



b- sandwich Winding



a- concentric Winding

Figure 4.12 Transformer Windings Types

(L) from Low and H from High in Fig. (B) to low voltage and high voltage coils respectively. **The winding can also be classified as follows:**

(A) Cylindrical Concentric Helix Winding: This type is commonly used in heart-shaped transformers and generally leaves axial distances between the coil and the insulating cylinder that surrounds the heart by placing axial (slices)plates to facilitate the oil circulation of the pipette. Sometimes the coil is made of two or more layers.

(B) Crossover Winding: These coils are suitable when the current does not exceed 20 amps. It is used in high voltage coils in relatively small transformers. The coils are placed around a forming tool in many layers, winding and reaching the sections of the coil respectively, and separating the sectors from each other with bits of insulating material to allow the passage of the cooling oil.

(C) Disc Winding: These coils are built from several flat sectors and include spiral layers from inside and outside. This type of coil is characterized by the mechanical strength of the roll, as well as the contact of each roll to cooling oil, which increases the efficiency of the cooling process.

3-Insulator:

The insulators are placed between high and low voltage windings and other insulators are placed between the low winding and iron core. These insulators are loaded with bakelite drums or galvanized casings, while conductors insulator can be paper, cotton or glass tape. The latter is used in transformers with air Insulated Transformer. It should be noted that the final winding in the high-voltage winding has a large piece of insulation because it exposed to a very high voltage compared to its counterpart in the middle of the winding when the process of turn on and turn off from the source. Strengthen the final coils is a good design step. Simply increasing the thickness of the insulator increases the voltage of the transformer to resist transient pulses.

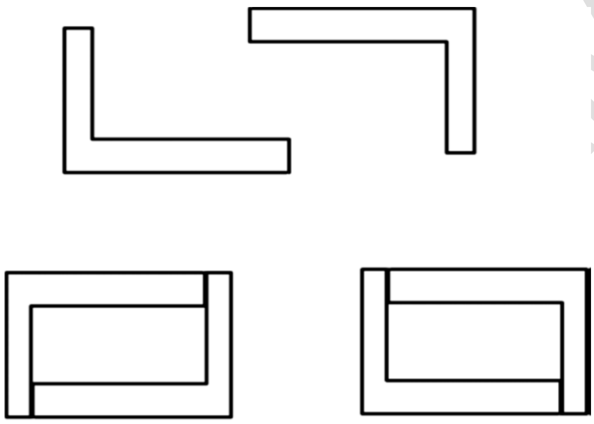
4-wires and conduction:

Copper bars are used to connect the windings to the Busbar directly in air-cooled transformers and are used for insulating bushing at the top of the oil receptacle in oil-cooled transformers.

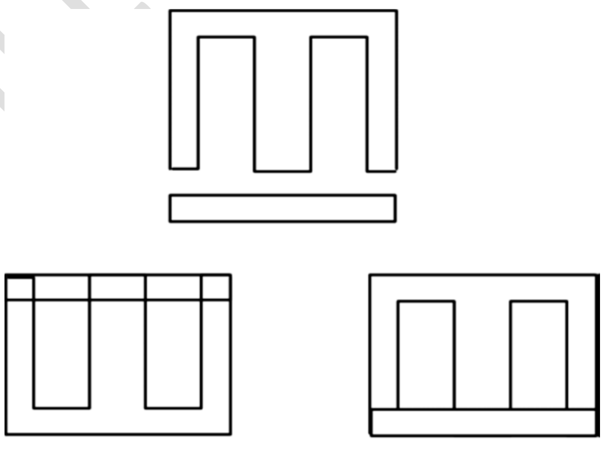
5. Bushings:

Ordinary Porcelain insulators are used for voltages up to 33 KV. When the voltage exceeds this value can be used capacitance bushings or bushings filled with oil. In some cases, they can be used together.

Generally in terms of windings position of the iron heart there are two types of transformers as shown in Figure (4.13). The first is called the Iron Core (Core Type), which the windings wrap around the iron heart as in Figure (4.13) a. The other is called (Shell Type), in which iron heart surrounds the windings shaped a shield component, as in Figure (4.13)b.



a-Core Type



b- Shell Type

Figure 4.13 iron heart, according to windings position

The principle and theory of the transformer operation

The operation of the transformer depending on **mutual induction** between two circuits linked by a common magnetic flux. In its simplest form, it consists of two inductive coils which are electrically separated but magnetically linked through a path of low reluctance, If one coil is connected to a source of alternating voltage, an alternating flux is set up in the laminated core creates in the iron heart magnetic flow (Magnetic flux). Most of Magnetic flux is linked with the other coil in which it produces mutually induced (e.m.f.) (according to Faraday's Laws of Electromagnetic Induction).

The ideal transformer and the equivalent circuit

An ideal transformer is one which has no losses, i.e. its windings have no ohmic resistance, there is no magnetic leakage and hence which has no core losses. In other words, an ideal transformer consists of two purely inductive coils wound on a loss-free core. The ideal transformer is a theoretical assumption only to understand the real transformer. These assumptions help to infer the different relationships. The ideal transformer is made up of two coils that have only an implicit impedance wrapped around an iron core If the primary coil is connected to an alternating voltage source, it produces a magnetic flux that depends on the voltage and frequency values as well as the number of primary coils. This flow is intertwined with the secondary coil and generated an AC voltage whose value depends on the number of secondary coils.
Suppose that the initial voltage is V_1 as in Figure 4.14, and the resulting magnetic flux is (φ), an opposite electric force of E_1 is generated, and its linear value is determined by Linz's law, and from the equation,

$e_1 = - N_1 \, d\varphi / dt$ Volt .... (1)
Where N_1 is the number of the primary coils. If we consider the resistance of the primary coils is zero, then the value of the voltage of V_1 is equal and opposite to E, that
$V_1 = N_1 \, d\varphi / dt$ Volt .... (2)
The input voltage equation can also be written in the secondary coil as follows,
$e_2 = V_2 = N_2 \, d\varphi / dt$ Volt .... (3)
Where N_2 is the number of secondary coils, and e_2 is the inverse E.M.F produced from it. By dividing equation (1) on equation (3) we obtain the following percentage,
$V_1 / V_2 = e_1 / e_2 = N_1 / N_2$ .... (4)

Where (N_1 / N_2) know as the transformer ratio,
If it is, $N_1 > N_2$
Then the transformer called a Step-down transformer,
Either if, $N_2 > N_1$

The transformer is then called a Step-up transformer.
Since the ideal transformer transfers the electrical power without loss of energy, the instantaneous power is equal to both sides of the transformer as in the following equation:
$V_1 * I_1 = V_2 * I_2$ .... (5)

Equation (4) and Equation (5) can establish the relationship between the current in the primary and secondary coils.

$I_1 / I_2 = N_2 / N_1$ .... (6)

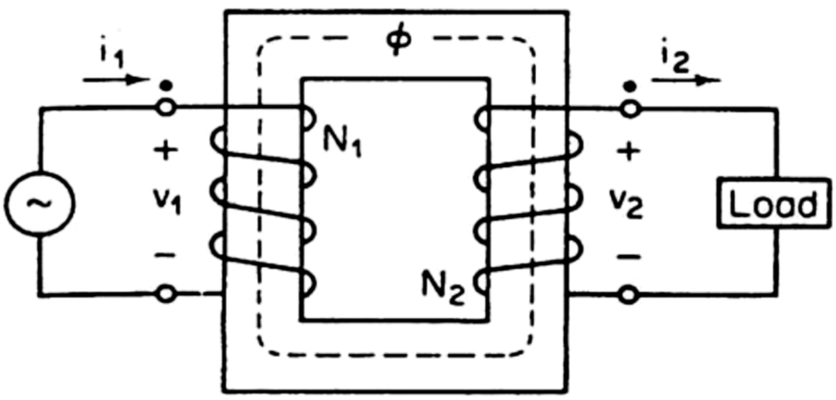


Figure 4.14 Idial Transformer

Let N_1 = No. of turns in primary
N_2 = No. of turns in secondary
Φ_m = Maximum flux in the core in Webers
$= B_m \times A$
f = Frequency of a.c. input in Hz

flux increases from its zero value to maximum value Φ_m in one quarter of the cycle *i.e.* in (1/4 *f)* second.

∴ Average rate of change of flux = $\frac{\varphi m}{\frac{1}{4}f}$

$= 4 f \Phi_m$ Wb/s or volt

Now, the rate of change of flux per turn means induced e.m.f. in volts.
∴ Average e.m.f./turn = $4 f \Phi_m$ volt
If flux Φ varies sinusoidally, then r.m.s. value of induced e.m.f. is obtained by multiplying the average value with the form factor.

Form factor = $\frac{\text{R.M.S.Value}}{\text{Average Value}}$ = 1.11.

∴ r.m.s. value of e.m.f./turn = $1.11 \times 4 f \Phi_m = 4.44 f \Phi_m$ volt

Now, r.m.s. value of the induced e.m.f. in the whole of primary winding
= (induced e.m.f/turn) × No. of primary turns
$E_1 = 4.44\, f\, N_1\, \Phi_m = 4.44\, f\, N_1\, B_m\, A$
Where the form factor of the sinusoidal wave is 1.11.

Losses and Efficiency

There are two types of losses in the transformers, iron losses and copper losses. Iron losses are usually constant and does not depend on the load. Copper losses depend on the load as it is proportional to the current square.

The efficiency of the transformer is usually calculated in terms of output power and the losses consumed by the transformer as in the following relationships:

$\eta = P_2 /(P_2 + P_{iron} + P_{cu}) * 100\%$

$\eta = P_2 / P_1 * 100\%$

Where P_2 load power and P_1 input power of the transformer.

$P_2 = V_2\, I_2\, COS\, (\varphi_2\,)$

Where ($COS\ \varphi_2$) is the power factor(PF).

Example (4-1):

A single-phase transformer with a capacity of 5 kVA, with a voltage of 440/110 volts and operating at 60Hz. Feeding load by a current 40 amperes at an advanced power factor of 0.8 at rated voltage. As the transformer is ideal, calculate the primary voltage and current, impedance of the load.

Solution:

$V_2 = 110\angle 0$ volt
$I_2 = 40\angle cos\text{-}1\ 0.8$ A
$I_2 = 40\angle 36.870$ A
The transformer ratio is

$V_1/V_2 = N_1 / N_2 = 4$

Thus

$V_1 = 440\angle 0$ volt

$I_1 = N_2/N_1 * I_2 = 1/4\ (40\angle 36.870) = 10\angle 36.870$ A

The load impedance is

$Z_2 = V_2 / I_2 = 110\angle 0 / (40\angle 36.870) = 2.75\angle -36.870\ \Omega$

Example (4.2):

A Single phase transformer with 200 kVA and 6600/400 volts with 80 turns in secondary coil and 50 HZ. Find,

1 - the number of primary coils.

2. Maximum magnetic flux.

If this transformer uses a frequency of 25 HZ and assuming that the magnetic flux has changed by 10%. Find,

3. New rated voltages

4. The amount of rationing in kilowatts of ampere, assuming that the current density of the coils has not changed.

Solution:

1- Primary coils, $N_1 = 80 * 6600/400 = 1320$ T

2- $E_2 = 4.44\ f\ N_2\ \phi_{max}$

$400 = 4.44 * 80 * 50 * \phi_{max}$

$\phi_{max} = 0.0225$ web.

3- The flow at 25 HZ is equal

ϕ_{max} (25 HZ) = 0.0225 * 1.1 = 0.02476 web.

4- Primary voltages at 25 HZ are equal

E_1 (25 HZ) = $4.44\ f\ N_1\ \phi_{max}$ (25 HZ)

= 4.44 * 1320 * 25 * 0.02476 = 3630 V.

4.6 AC Generators

Basic Generator Construction

The base generator consists of a magnetic field, Rotor (armature), slip rings, brushes. The magnetic field is usually the result of an electric magnet. The rotor is composed of conductive wires wrapped in the form of coils (rings) that revolve in the magnetic field as shown in Figure 4.15.

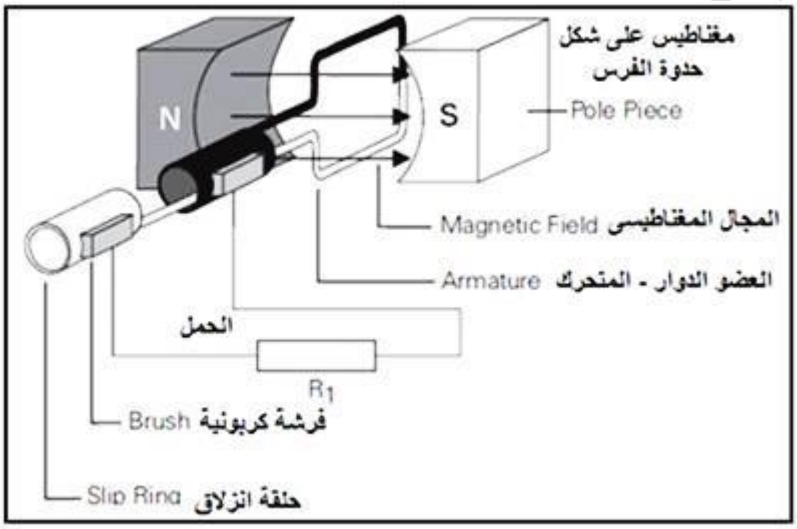


Figure 4.15 Basic Generator Construction

Practical AC generators differs from simple AC generators in many ways. Practical generators are equipped with an additional generator known as an exciter. The exciter provides a direct current to the electric magnet that is used to create a magnetic field within the alternating generator. The AC generator is composed of copper wires wrapped in the form of hundreds of coils around holes engraved in an iron heart. Some of AC generators are called single-phase alternating current generators, which have a set of coils similar to the number of poles in the structure of the field. But most of AC generators have three sets of coils per pole, so they produce three currents at the same time, these types of generators are known as three-phase generators. These generators produce greater power than single-phase generators and improve power transmission.

4.7 Types of Single-Phase Motors

Such motors, which are designed to operate from a single phase supply, are manufactured in a large number of types to perform a wide variety of useful services in home, offices, factories, workshops and in business establishments etc. Small motors, particularly in the fractional kilowatt sizes are better known than any other. Since the performance requirements of the various applications differ so widely, the motor-manufacturing industry has developed many different types of such motors, each being designed to meet specific demands. Single-phase motors may be classified as under, depending on their construction and method of starting:

1. Induction Motors (split-phase, capacitor and shaded-pole etc.).

2. Repulsion Motors (sometime called Inductive-Series Motors).

3. A.C. Series Motor.

4. Unexcited Synchronous Motors.

But our important here is to study the induction motors.

4.8 Single Phase Induction Motors

Parts of a single-phase induction motors

AC motors consist of main parts that are present in all types, and additional parts are only present in some.

Main parts

1. Stator

It consists of three basic parts,

A) Yoke (Frame):

Made of steel (cast iron) or aluminum with fins on its outer surface to cool the coils through the air from the fan cooling. The frame is used to carry the chips of the heart and fixed the covers and the coupler box as well as to complete the magnetic cycle of the poles.

B) Stator:

It is made of silicon chips, with thickness from 0.35-0.5 mm, for low-power motors, isolated with varnished and thermally compressed, with longitudinal ducts on a stator which coils are placed. In some motors, as in the split phase, two units of isolated copper coils are wrapped. One of them is called main or (running) coils, and the other called starting or (auxiliary) coils.

C) Stator Coils:

It is made from copper wires isolated by varnishes and wrap on a piece with special size and a number of coils suitable to power of the motor. It is divided into two parts: Running coils and starting coils.

Running coils: Which are the main coils and be wrapped in a thick wire insulated with varnish. Number of coils are more often and not separated from the circuit only if the current completely disconnected from the motor. In some motors, as in the split phase, the main coils occupy two thirds of the number of ducts.

2 - Rotor

It is a type of squirrel cage where it consists of three basic parts. The first part is the heart, composed of thin steel sheets with high-quality of electrical properties called chips, the second part is the shift, where the heart chips are assembled and thermally pressed with it. The third part is the squirrel cage coils, which consists of thick copper rods are placed in the ducts of iron heart. The ends of the bars are welded on both sides by two closed rings of the same metal rails.

3- The two covers

They are made of steel (cast iron) or aluminum that is same for the frame metal and are fixed by special screws. One of them is front and the other one contains the wheelchairs which are mounted on the shaft. They work on balancing the rotor and facilitate the movement of the rotor and make it free to move.

4- The ventilation fan

It is an important part where it is made of aluminum or plastic. During the rotation of the motor, the air flows between the frame fins, so it reduces the temperature that arises from passing the current in the iron heart coils of the stator.

Additional parts

1. Centrifugal Switch:

Found in split phase motors. It consists of two parts, one of which is located on the spindle and is affected by the centrifugal forces resulting from rotor rotation. The other part, with the contacts, is placed on one of the two covers in front of the first part. The switch opens and closes the two touch points in the starting coils. When the rotation starts, the two points are closed, to completing the circuit for passage the current in the starting coils. After the rotation of the rotor reaches **75%** of the rated speed, the two contact points are opened by the centrifugal force influencing the moving part of the switch. When the motor is turned off, the pressing disc returns to its position, closes the two contact points and completes the starting coil circuit. Figure 4.16 shows the shape of the centrifuge switch.

2. Starting Capacitor:

Its add to the single phase motor with starting coils to increase torque and reduce consumption of the current. And connects in the starting coils, whether there is a or without a centrifuge switch as some capacitors start the period of operation with the starting coils without a switch cut off from the circuit. There are different types of capacitors: paper capacitors, filled capacitors with oil or with liquid electrolyte.

3. Starting coils:

Which are auxiliary coils are found in split phase motors where occupying one third of the number of ducts and wrap with a thin wire and lower number of coils. These coils are placed leading or lagging from the running coils at an angle of (90) electrical degree to be another face helps to find a magnetic field rotary.

4. Rings of copper or aluminum:

Is a coil made of copper or aluminum wire placed in its stream (ducts) that is on one side of each pole and surrounded by the main coils wrapped on the poles. These shaded coils act as starter coils.

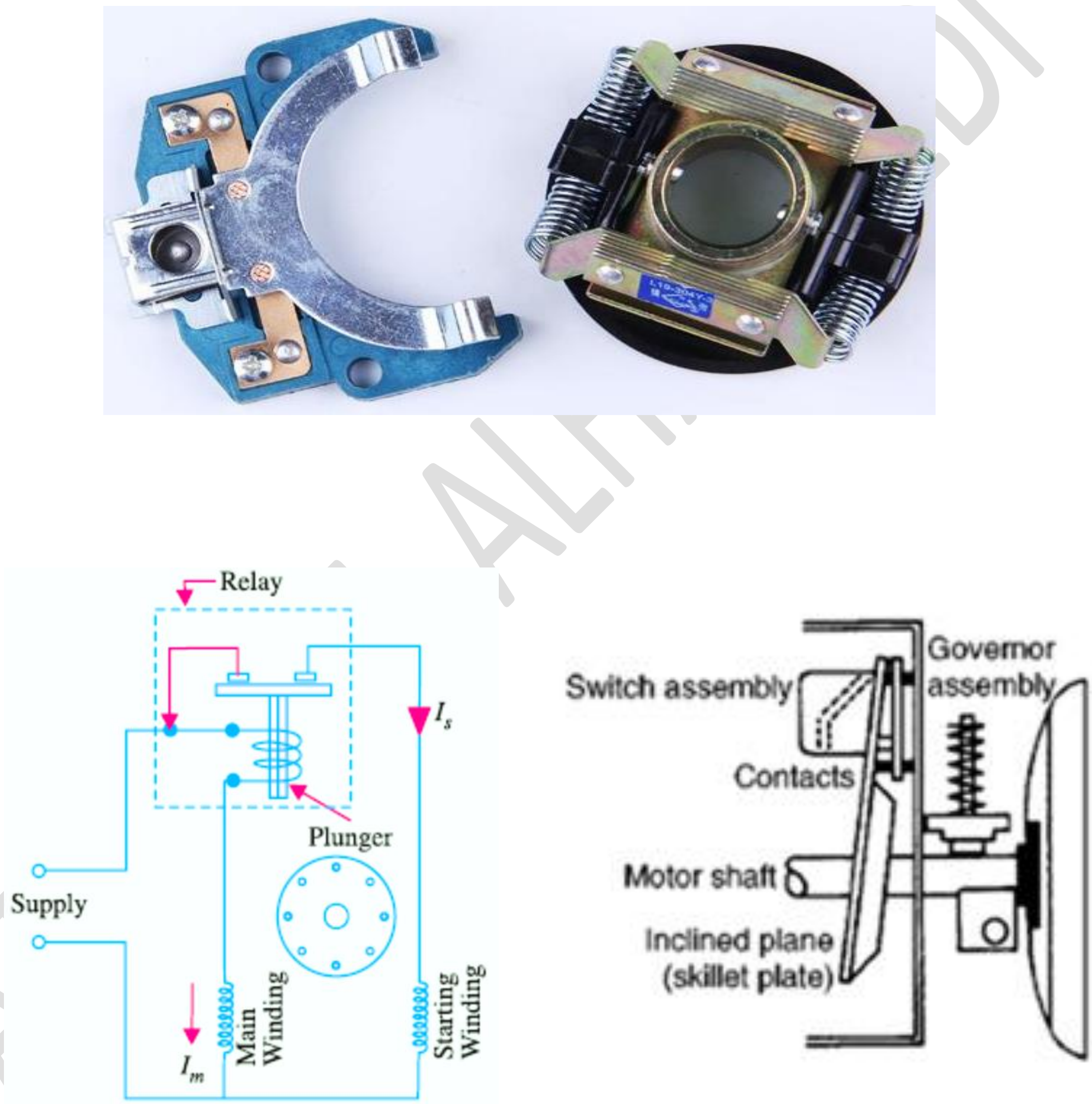


Figure 4.16 Centrifuge switch

Theory of operation of a single phase induction motor

The single motors operate on the principle of electromagnetic induction when the current passes through stator coils, fixed two-unit coils separated by a 90-electrical degree. A circular magnetic field is created. This area is cut the rotary cage coils and generates a current by effect. This generated current creates a new magnetic field that conflicts with the original field. A repulsion leads to the generation of circular torque or circular mechanical force that moves the rotor and makes it continue to spin until it reaches its rated speed and moving a load with it by the shaft. The stator of a single-phase motor is provided with an extra winding, known as **starting** (or auxiliary) winding, in addition to the **main or running winding**. The two windings are spaced 90º electrically apart and are connected in parallel across the single-phase supply as shown in. It is so arranged that the phase-difference between the currents in the two stator windings is very large (ideal value being 90º). Hence, the motor behaves like a two phase motor. These two currents produce a revolving flux and hence make the motor self-starting.

The single phase induction motors types

As discussed above, a single-phase induction motor is not self-starting. To overcome this drawback and make the motor self-starting, it is temporarily converted into a two-phase motor during starting period. **For this purpose, There are different types of alternating current motors:**

1-Split-phase Induction motor

It is one of AC motors with fractional horsepower, and is often used to operate some household appliances such as washing machines, small pumps, fans, automatic music devices ... etc. It is called by this name because it cannot start its movement when feeding its main coils from the single-phase voltage, so it has been divided into another by using a starting coil with a capacitor. In split-phase machine, the main winding has low resistance but high reactance, whereas the starting winding has a high resistance, but low reactance. The resistance of the starting winding may be increased either by connecting a high resistance R in series with it or by choosing a high-resistance fine copper wire for winding purposes. It is so arranged that the phase-difference between the currents in the two stator windings is very large (ideal value being 90º). Hence, the motor behaves like a two phase motor. Figure 4.17shows the electric circuit of the split phase motor. The motor consists of two parts, the first of which is a rotating part called rotor and the second part is a static part called the stator. The rotor is installed centrally within the stator in a mechanical manner, that feeding from a single phase power.

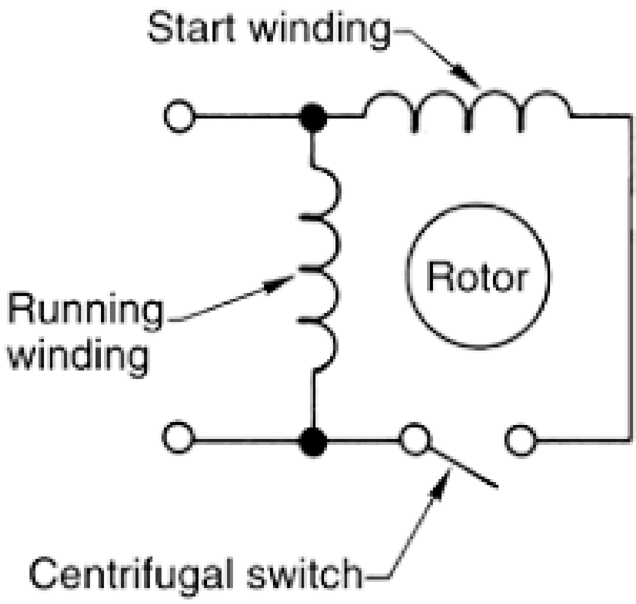


Figure 4.17 Electric circuit of the split phase motor

Centrifuge switch: As explained previously. The start coils are then needed at startup to help generate the permanent magnetic field and then be eliminated and separated from the circuit by the centrifuge switch when the motor speed reaches 75% or 80% of its rated speed. The function of the centrifuge switch is to prevent the motor from pulling more line current and protecting the starting coils from damage due to high temperature.

In the case of split-phase motors that are hermetically sealed in refrigeration units, instead of internally-mounted centrifugal switch, an electromagnetic type of relay is used. As shown in Figure (4.16), the relay coil is connected in series with the main winding and the pair of contacts which are normally open, is included in the starting winding.

During the starting period, when (Im) is large, relay contacts close thereby allowing (Is) to flow and the motor starts as usual. After motor speeds up to **75** per cent of full-load speed, (Im) drops to a value that is low enough to cause the contacts to open.

2. Capacitor Motor

This type of motor works on AC and is manufactured in sizes ranging from (1 - 20) horsepower. It is widely used in many devices like air conditioners and washing machines etc. Capacitor motor is similar to split phase motor, but it has an additional unit called the condenser. It shall have two basic types:

Starting capacitor motor: In this type, the condenser is connected continuously to starting (auxiliary) coils. This capacitor improves the angle of the face to approximate 90 °, as shown in Figure 4.18.

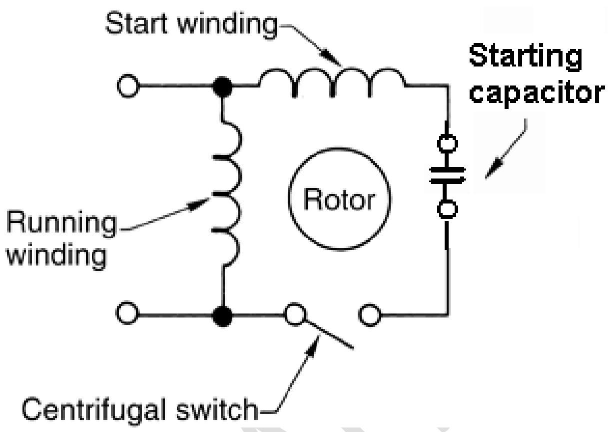


Figure 4.18 Starting capacitor motor

Permanent (Running) capacitor motor: In this type of motor connect the main coils directly to the AC feeding voltage, and the additional coils will be connected in series with the capacitor as shown in Figure 4.19.

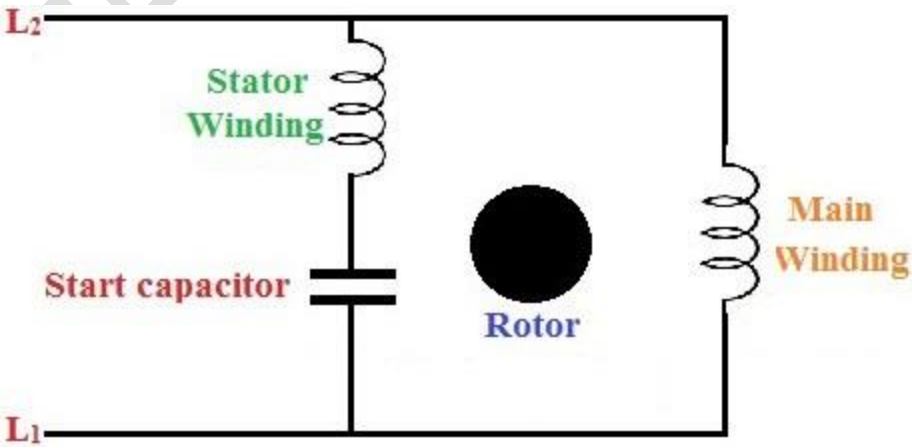


Figure 4.19 Permanent (Running) capacitor motor

Sometimes a third type, called dual capacitor motor, as shown in Figure 4.20.

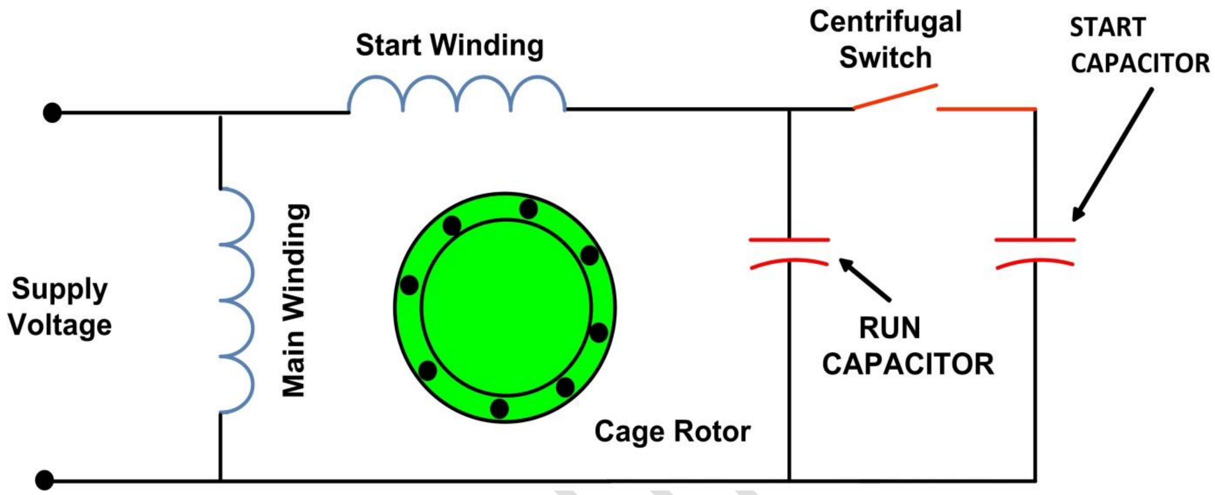


Figure 4.20 dual capacitor motor

3. Shaded pole motor

The shaded pole motor is a single phase motor with a power of approximately (0.01-0.35) horsepower. It is used in loads that require low initial torque such as fans, hair dryers and many other applications. These motors have salient poles on the stator and a squirrel-cage type rotor. Its rotor consists of a steel shift and a heart made of silicon steel sheets, that assembled in the form of a cylindrical shape, on its outer perimeter ducts with copper or aluminum rods(coils). Its terminals welded with two copper or aluminum rings. The shaded coils are copper wire with a large placed in its own stream (special ducts) on one side of the pole and is surrounded by the main coils wrapped on the poles. These shaded coils act as a starting coil. Figure 421 shows The shaded pole motor circuit.

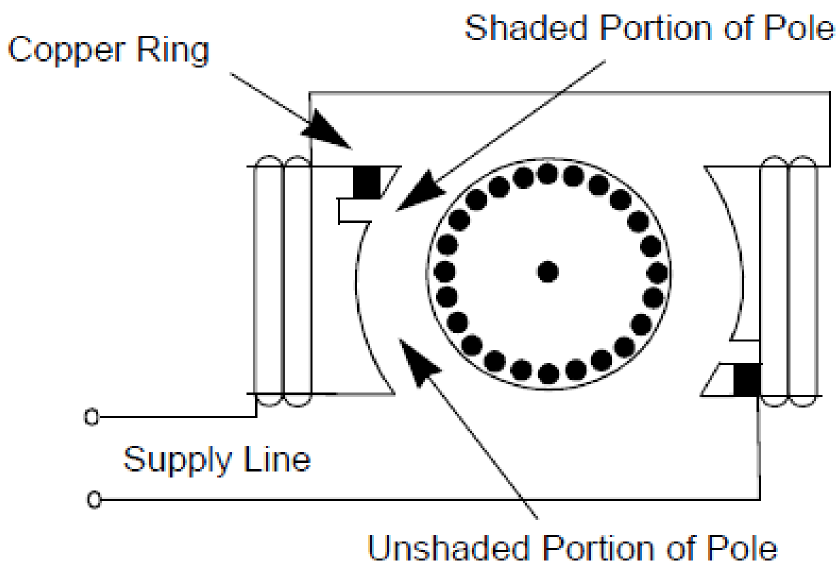


Figure 4.21 Shaded pole Motor circuit

4. Repulsion Induction Motor

It works on the combined principle of repulsion and induction. It consists of ***(a)*** stator winding ***(b)*** two rotor windings: one squirrel cage and the other usual d.c. winding connected to the commutator and ***(c)*** a short-circuited set of two brushes. It is particularly suitable for those applications where the load can be removed entirely by de-clutching or by a loose pulley. This motor is a combination of the repulsion and induction types and is sometimes referred to as **squirrel-cage repulsion motor**.

Universal Motor

A universal motor is defined as a motor which may be operated either on direct or single-phase a.c. supply at approximately the same speed and output.
It is a series-wound motor, it has high starting torque and a variable speed characteristic. It runs at dangerously high speed on no-load. As shown in Figure 4.22. Universal motors are used in vacuum cleaners where actual motor speed is the load speed. Other applications where motor speed is reduced by a gear train are: drink and food mixers, portable drills and domestic sewing machine etc.

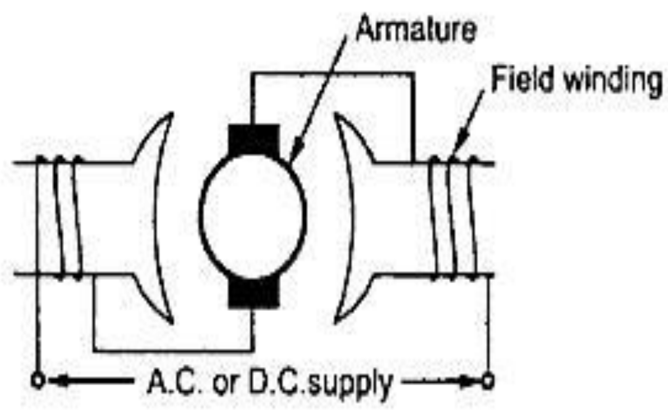


Figure 4.22 Universal Motor

QUESTIONS

***Q1**/(250 V, 25 KW) DC shunt motor has armature resistance of 0.06 Ω and shunt-field resistances of 100 Ω. Determine the back e.m.f., when the machine is:*

1. Works as a generator.

2. Works as a motor.

***Q2** / 240V DC shunt motor has armature resistance of 0.8 Ω and shunt-field resistances of 200 Ω. Determine the back e.m.f., when the output power is (10 HP) and 85% efficient.*

***Q3** / a single phase transformer contains 80 T in the secondary coil and works at 50 HZ frequency. If the ratio of secondary to primary coil voltage is (400/6600) Calculate:*

1 - The number of primary coils.

2. Maximum value of the magnetic flux.

***Q4** / single phase transformer with 50 kVA amp. Primary voltages (6600) volts , the secondary voltage (254) volts and the number of coils (32 T). Calculate the number of primary coils, and the both current of the primary and secondary, at full load.*

Q5/ A shunt generator delivers 450 A at 230 V. The resistance of the shunt field and the armature field are 50 Ω and 0.03 Ω respectively. Calculate the generated e.m.f.

Q6/A long-shunt compound generator delivers a load current of 50 A at 500 V and has armature, series field and shunt field resistances of 0.05 Ω, 0.03 Ω and 250 Ω respectively.
Calculate the generated voltage and the armature current. Allow 1 V per brush for contact drop.

Q7/ A short-shunt compound generator delivers a load current of 30 A at 220 V, and
has armature, series-field and shunt-field resistances of 0.05 Ω, 0.30 Ω and 200 Ω respectively. Calculate the
induced e.m.f. and the armature current. Allow 1.0 V per brush for contact drop.

Q8/ A 440-V, shunt motor has armature resistance of 0.8 Ω and field resistance of 200 Ω. Determine the back e.m.f. when giving an output of 7.46 kW at 85 percent efficiency.

Chapter Five

5.1 The Diod

The first to discover the properties of the diode was the physicist Fernand Braun in 1874 when he was working on research related to the electrical properties of what is known as the crystal oscillator. Since then, it has been discovered that when we form a semi-conductive material from silicon and add some impurities to it, we will get a positive semi-conductive material. In the same way, we add other impurities to get a negative semi-conductive material. When we connect these two pieces together a new element will form Called the diode. The diode passes a current when it is in forward bias, and does not pass the current when it is in the backward bias. Figure 5.1 shows the shape and electrical symbol of the Diod.

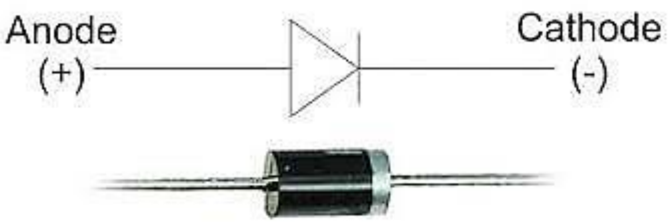


Figure 5.1 Shape and Symbol of the Diod

P-N Jection

The P-N Jection contains two components (anode and cathode), which are made of semiconductor materials (Silicon, Germanium).

Silicon and germanium belong to the semiconductor family. The silicon and germanium atoms contain four equal electrons (the valence electrons are the outer orbital electrons of the atom and contribute to the chemical reactions). The difference between them is that the silicon atom contains 14 protons in the nucleus while the germanium atom contains 32 Proton. In order to transform pure crystalline into a conductive material, it is injected with one of the materials called "impurity materials".

Where a third valence impurity material is used to form the positive crystal such as indium (IN), gallium (GA) and boron (B), while a fifth valence impurity material is used to form the negative crystal such as phosphorus (P), zinc (AS) and antimony (SB). The pn-junction contains two pairs of crystals, one negative and the other positive, connect the positive junction (P-type), which contains the positive gaps as charge carriers with the negative junction (N-type), which contains the negative electrons as carriers of the charge. The line that separate between the two types, called the Junction.

Diode properties and methods of connections (bias)

The diode allows the electric current to pass in one direction when the anode voltage is positive when the battery is connected (forward bias). This occurs when the forward voltage (supply voltage) exceeds the forward bias voltage, the value of the forward bias voltage in the silicon diodes (0.7) volts and the germanium bias (0.3) volts. While when the anode voltage is negative when the battery is connected (reverse bias). Very little current is passing. When the reverse bias voltage is increased so that the voltage reach the breakdown voltage, a breakdown occurs and a very high current is passing, if its value does not limit, it can cause diode damage. Thus, the diode can be considered as a switch that passes the current in one direction and does not in the other. Figure 5.2 shows the curve of the properties of the diodes in both cases (forward bias and reverse bias). Figure 5.3 shows how the diode is connected in both cases (forward bias and reverse bias).

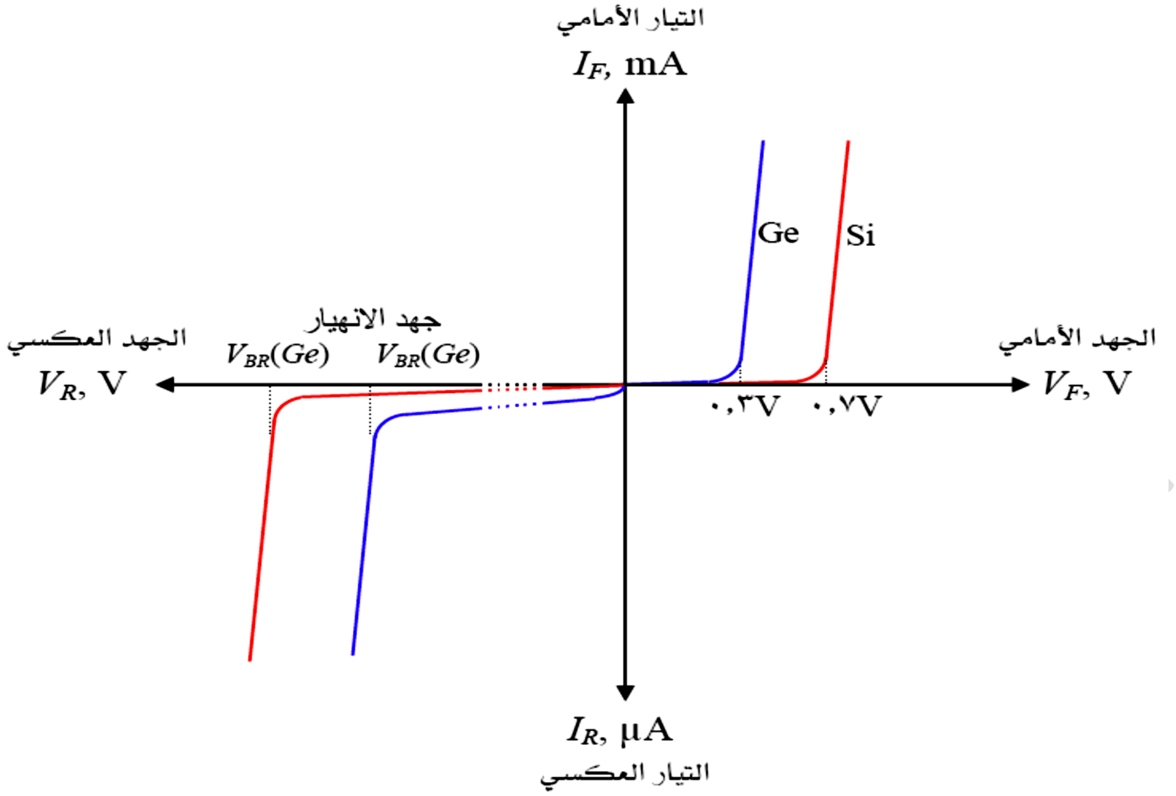


Figure 5.2 The curve of the properties of the diodes

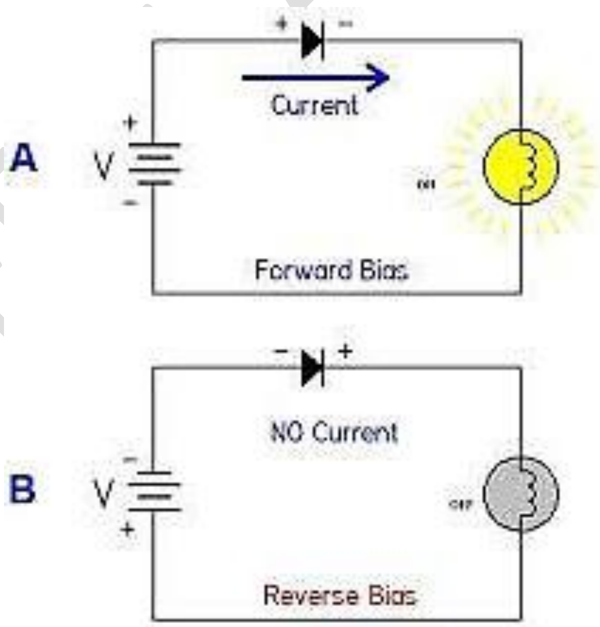


Figure 5.3 The diode connection in both cases (forward bias and reverse bias).

5.2 Use the diode as Rectifier

Uncontrolled Rectifier:

An electrical component that converts the (AC) wave (alternating current) to (D.C) a direct current wave. It is commonly used in many electrical applications and electronic devices such as electric charger.

1- Half-wave rectifier.

2- Full-wave rectifier using two diodes.

3- Full-wave rectifier using four diodes.

1. Half Wave rectifier

If the diode is connected to a load as shown in Figure 5.4, in the half of the positive wave of the voltage (depending on connecting the diode in the circuit) in the case of forward bias, it will pass the current and will behaves like a closed switch. In the half of the negative wave, the diode will not pass the current because the voltage applied to it is in the direction of reverse bias. Figure 5.4 shows a half-wave circuit while Figure 5.5 shows the input and output waves.

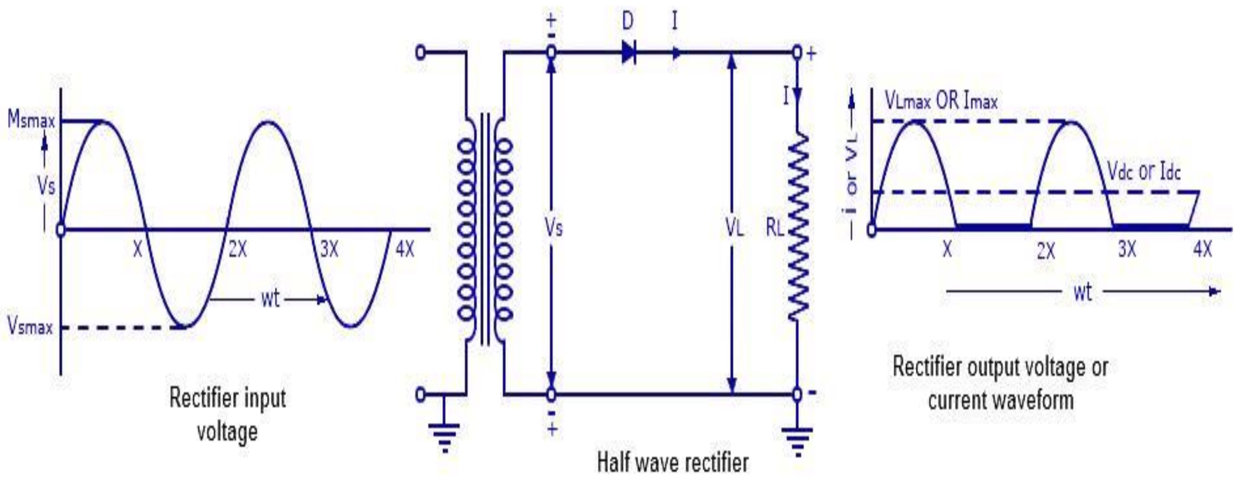


Figure 5.4 Half-wave circuit

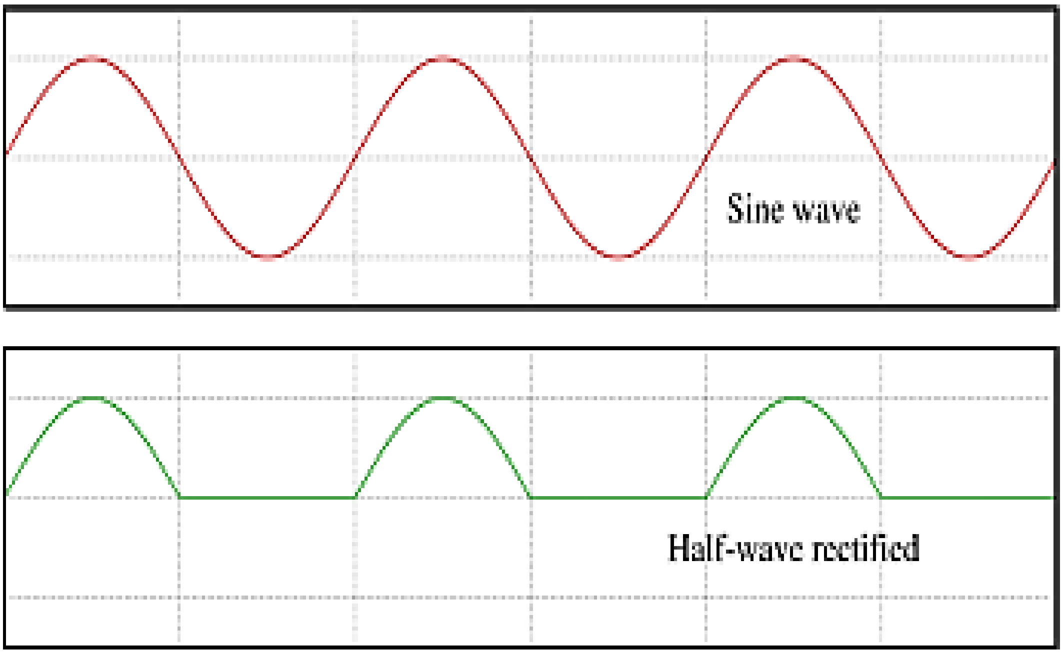


Figure 5.5 The input and output waves

2- Full-wave rectifier using two diodes

At the positive half of the applied wave, the upper diode is connected to the forward bias, so allowing half of the positive wave to pass through the load impedance, at the same time the lower diode is connected to the reverse bias. At the negative half of the applied wave, the lower diode is connected to the forward bias, so allowing half of the negative wave to pass through the load impedance in the same way and in the same direction as the positive half. At the same time, the upper diode is connected to the reverse bias.

Thus, it passes through the resistance load the positive half waves in one direction, so the output wave is similar to D.C but it differs in the stability of its value. Figure 5.6 shows the full wave rectifier and Figure 5.7 shows the input and output waves.

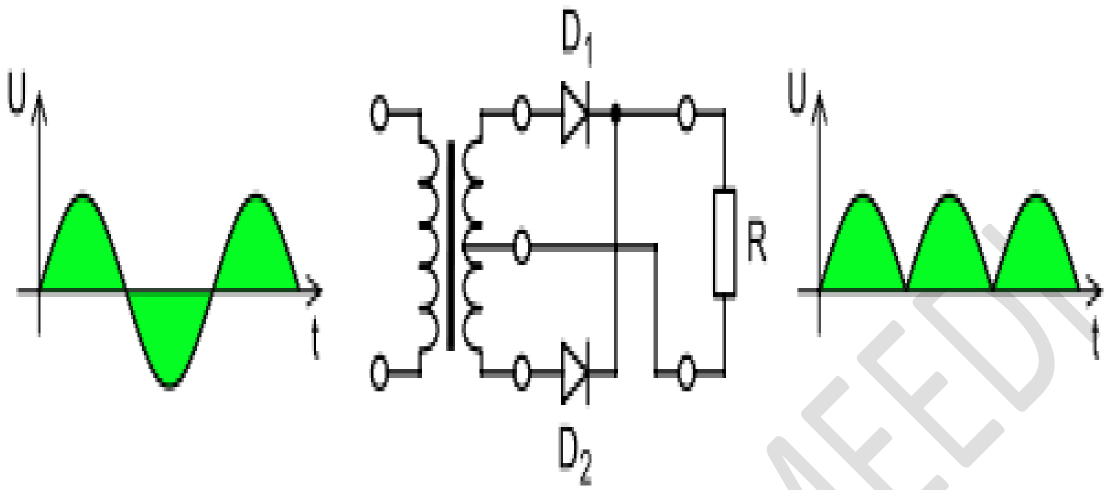


Figure 5.6 The full wave rectifier

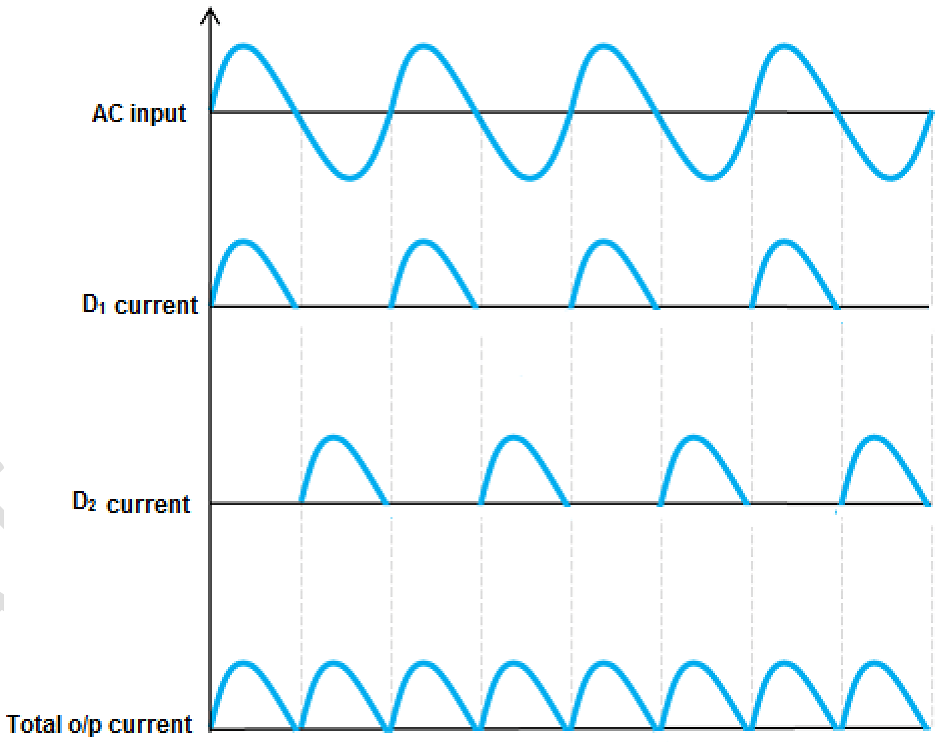


Figure 5.7 The input and output waves

3. Full waveform (Bridge) rectifiers

In this type of rectifiers, four diodes are used to form as a Bridge, and a two terminal transformer is used instead of the mid-type transformer.

During the positive half wave: The diodes D1 & D3 are forward biased and the diodes D2 & D4 are reverse biased, so the current passes from the transformer to the load resistance during D1 and from the load resistance to the source back again through D3.

During the negative half wave: The diodes D1 & D3 are reverse biased and the diodes D2 & D4 are forward biased, so the current passes from the transformer to the load resistance during D2 and from the load resistance to the source back again through D4.

Figure 5.8 shows complete bridge rectifier using four diodes, while the figure (5.9) shows the input and output waves.

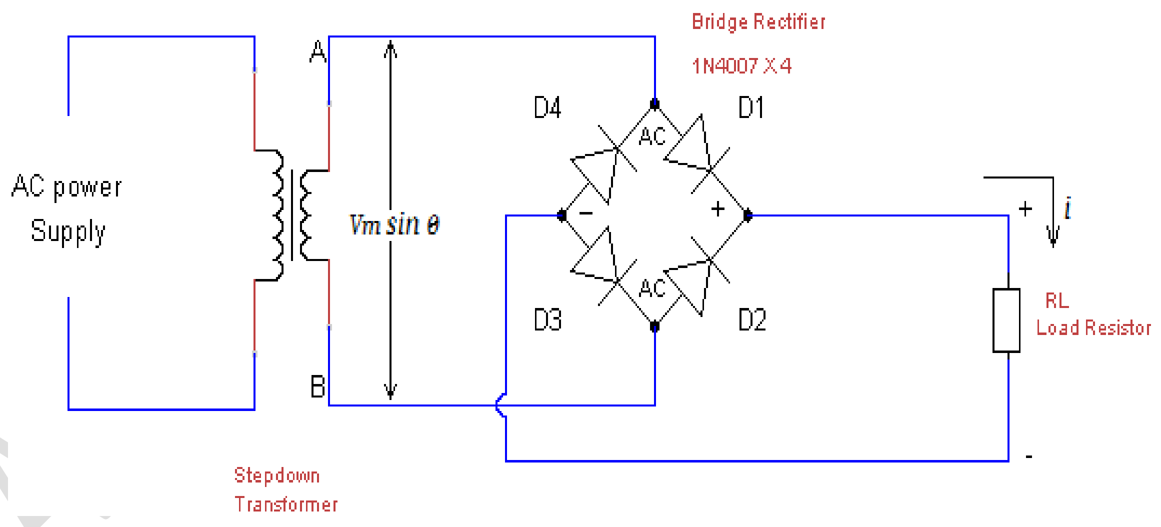


Figure 5.8 Bridge Rectifier

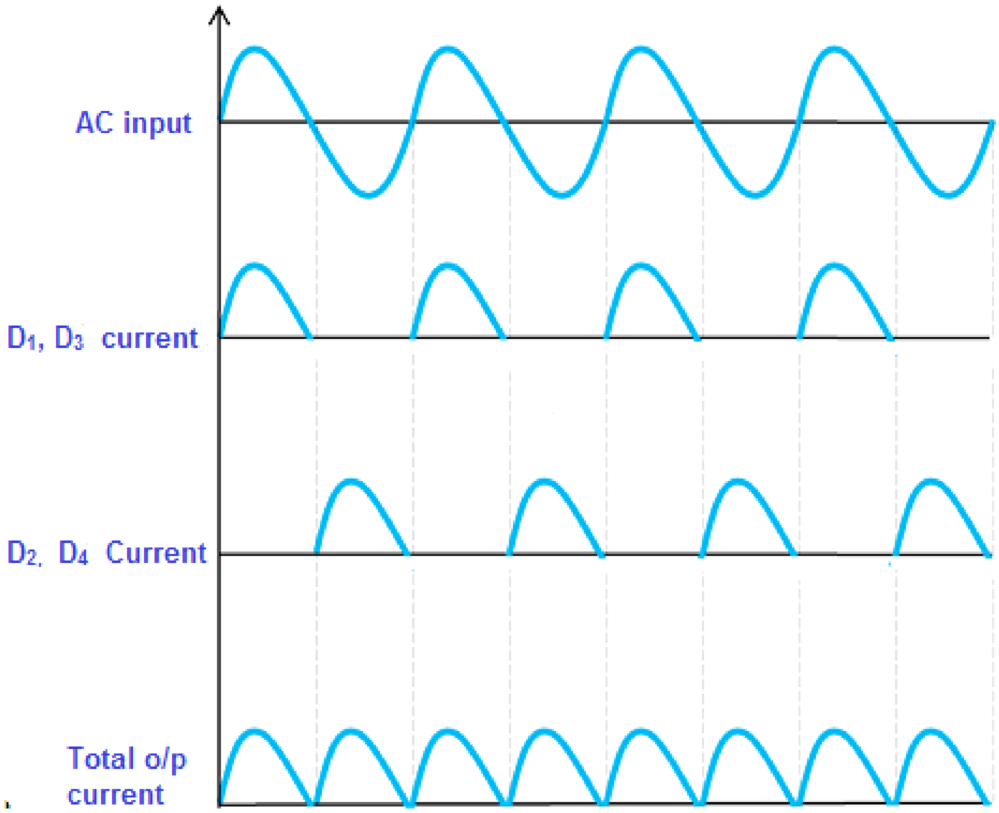


Figure (5.9) The Input and Output Waves of the Bridge rectifier

5.3 Smoothing Circuits

In the previous rectifier circuits, whether the half wave or full wave rectifiers the current passes in the load resistance is the positive halfs waves, has a constant direction, but its value is not constant, so there is a way to convert this current into a pure direct current called (Smoothing).

The smoothing circuits contain capacitors in addition to the coils or resistors. The capacitor stores the voltage during the positive half wave increasing to the full charge and then discharge this voltage during the positive half wave decreasing, so the current with a constant value will pass through the load resistance. The coils represent impedance to the AC power passage.

The smoothing circuits may be simple and contain a single capacitor that is T-shaped or contains two capacitors. Figure 5.10 shows one capacitor circuit and the output wave.

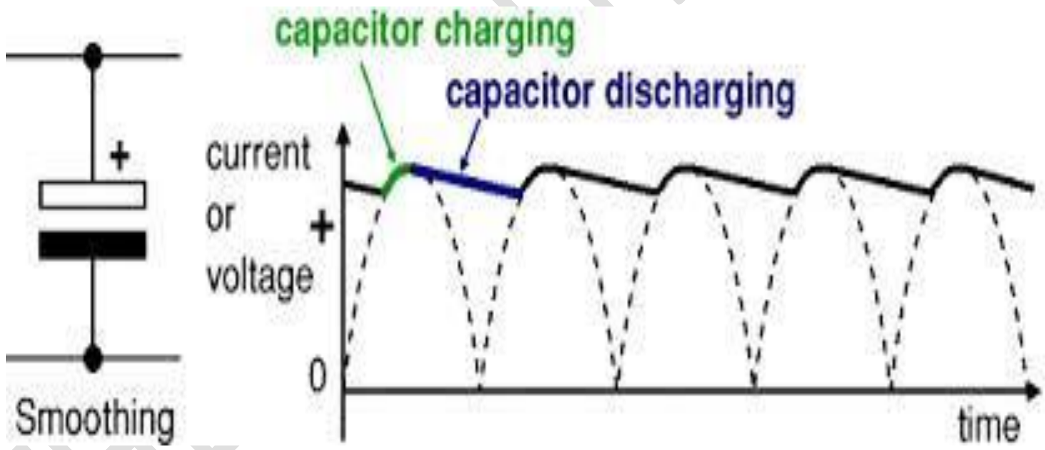


Figure 5.10 One Capacitor Smoothing Circuit and the Output Wave

5.4 Thyristors

The word Thyristor is a Greek origin, which means the door. This is in the language. When going to the electronic concept, the Thyristor is an electronic component made of semiconductor materials consisting of four layers and is in a sequence (P1, N1, P2, N2). It has three electrical terminals, Anode, Cathode and the Gate. Figure 5.11 shows the construction and electrical symbol of the Thyristor.

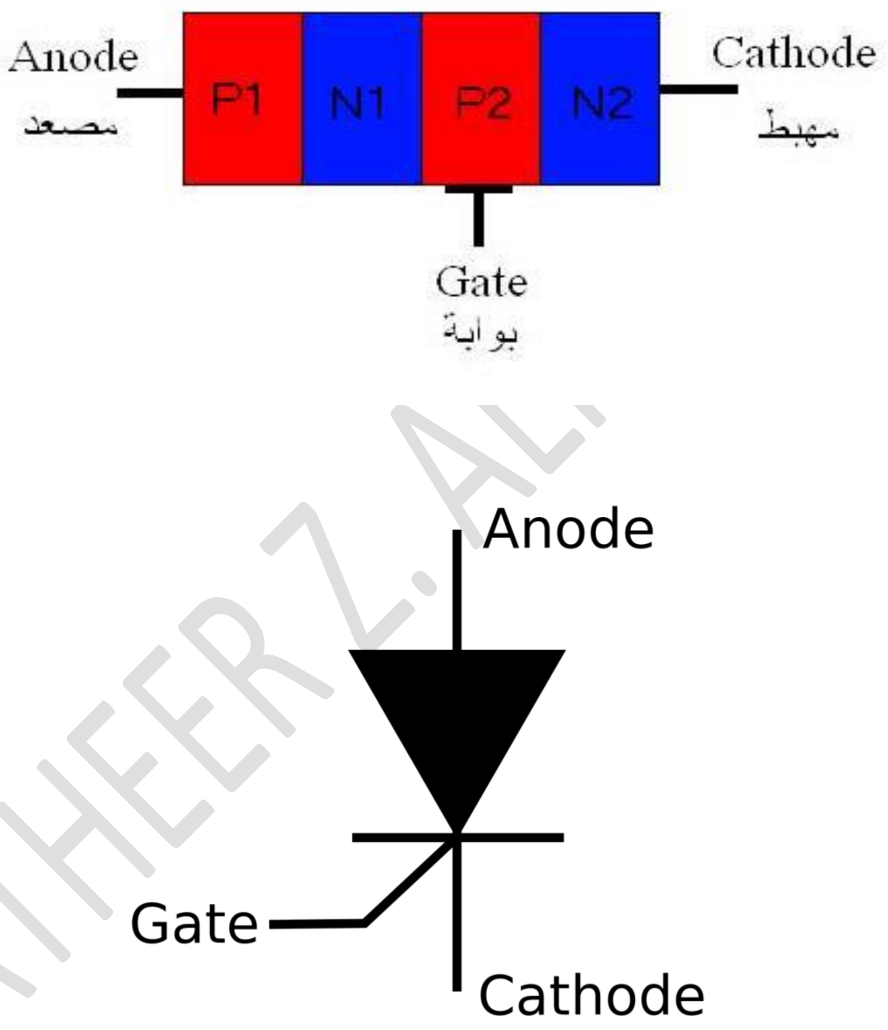


Figure 5.11 Construction and Electrical Symbol of the Thyris

To know Thyristor doing, we can represent it by two Transistors, the first Transistor (P1N1P1) and the second ((N2P2N2)) connected to each other as shown in Figure 5.12.

As we note that this strange connection to the Transistors is based on a principle called positive feedback, therefore, what is positive feedback?, it can be summarized electronically as a certain connection between the output and the input of an electronic circuit, which increases the gain of the circuit (either voltage or current) significantly. This can be applied to the Transistors circuit, when the current passes in the base of the Transistor Q1, its effect will be amplified on the collector of the Transistor Q1 that Connected to the base of the Transistor Q2 and therefore when the current passes in the base of the Transistor Q2, the Transistor Q2 work and passes the current from its emitter to the collector for the same Transistor that connected with the base of Transistor Q1, and thus increase the current of the base of the Transistor Q1. So we note that the Transistors are moving very quickly towards saturation.

The Thyristor is treated as an electronic switch, it takes two positions (cut or saturation) and remain in this state if no external power is affecting it.

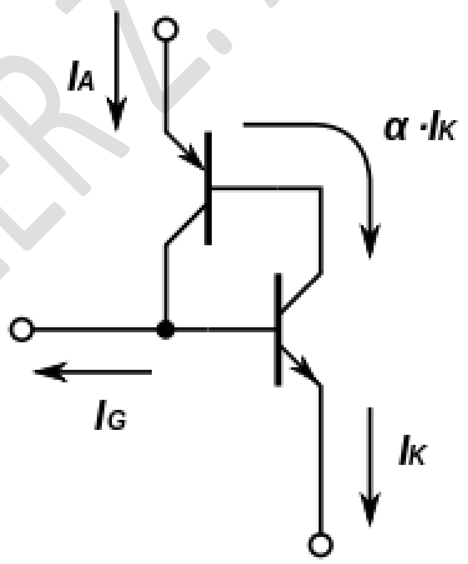


Figure 5.12 Thyristor Representation

In general Thyristor's work can be summed up (it resembles the work of diodes).

• **When it is forward biased:** Thyristor does not pass any current except If the anode to cathode voltage (VAK) is increased to the sufficient large value (the applied voltage is greater than the forward breakdown voltage (VBO)).

• **When it is reverse biased:** If reverse voltage is increased During reverse blocking if Ig = 0 then only reverse saturation current (Is) flows until the reverse voltage reaches the reverse breakdown voltage (VBR). At this point current starts rising sharply. Large reverse voltage and current generate excessive heat and destroys the device.

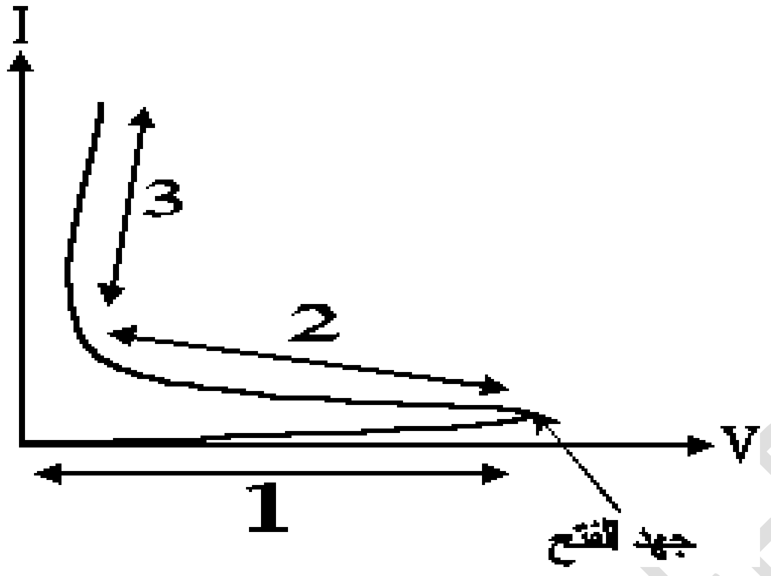
We can note that Thyristor work area represents in three regions as shown in Figure 5.13.

1 - Cutting (off) area: this occurs when the anode to cathode voltage VAK is less than (VBO), so Thyristor does not pass any current. The minimum anode current below which device stops conducting and return to its off state usually this value is very small in mA is called Holding Current (IH).

2 - Negative resistance area: occurs when the anode to cathode voltage (VAK) significantly decreases with increasing current.

It is a transient state between cutting and saturation and usually drawn in many references in a dotted line.

3. The working (on) area: the saturation area where the current passes in the Thyristor when the rated forward voltage is greater than the forward breakdown voltage (VBO) and the Latching-current (IL) condition occurs, Latching current IL is the minimum anode current required to maintain Thyristor in ON state immediately after Thyristor has been Turn ON and the gate signal has been removed.



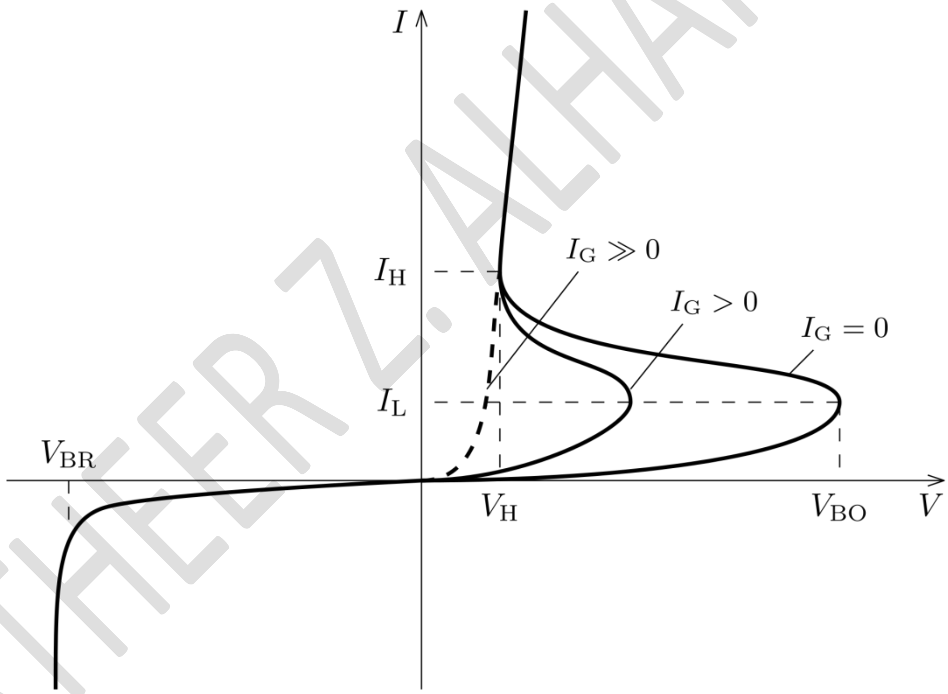


Figure 5.13 Thyristor Charactoristic Curve

5.5 Single Phase Full Wave Control Rectifier

It is one of the applications of the Thyristors. As shown in Figure 5.14, which uses a bridge circuit rectifier, where each Thyristors (SCR1 & SCR3) must be working together as a combined, as well as for (SCR2 & SCR4) they should be also working together as a combined. Thus the alternating current (AC) is converted into a direct current DC. Figures 5.15 and 5.16 shows the waveforms of the input and output voltages in case of the load changes and the firing angle of the Thyristor.

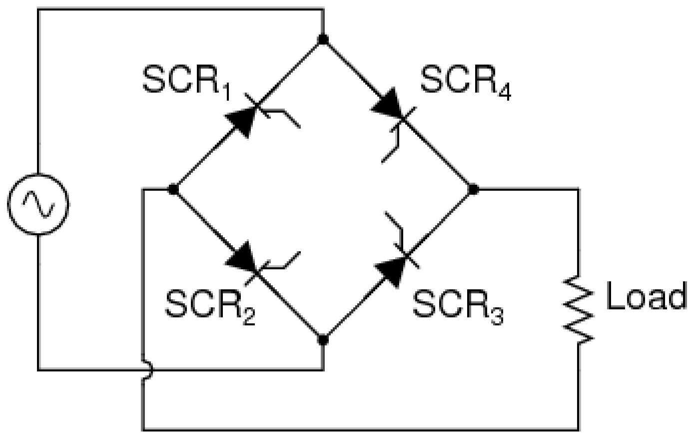
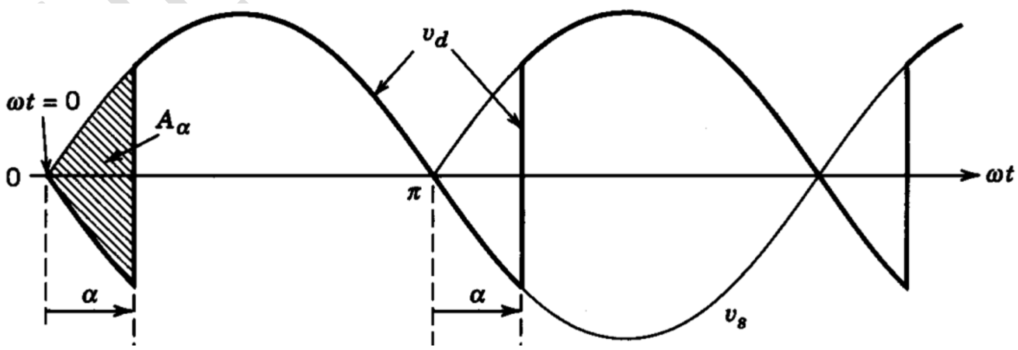
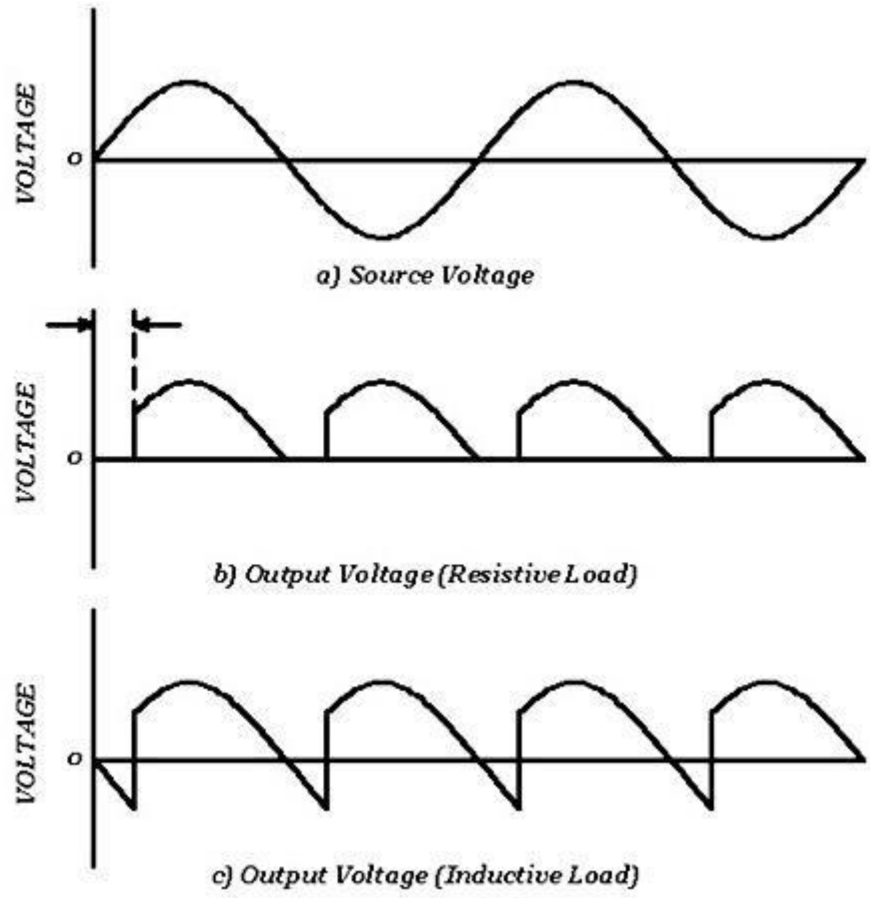


Figure 5.14 Single Phase Full Wave Control Rectifier



Figures 5.15 Input and output voltages with firing angle of the Thyristor in case of the load changes



Figures 5.16 Input and output voltages and the firing angle of the Thyristor

There are other types of full wave control rectifiers that using two Thyristors with a center tap transformer as shown in Figure 5.17, or using four Thyristors as shown in Figure 5.18.

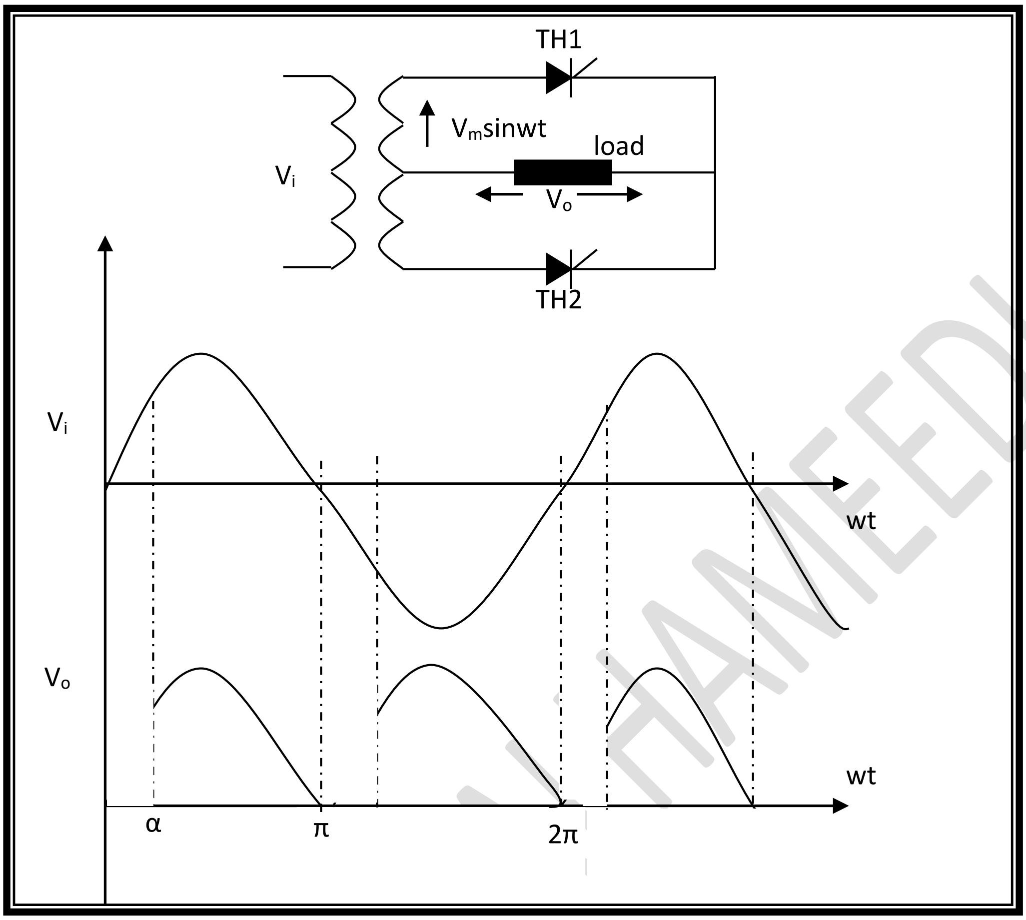


Figure 5.17 Full Wave Control Rectifiers Using Two Thyristors with a Center tap Transformer

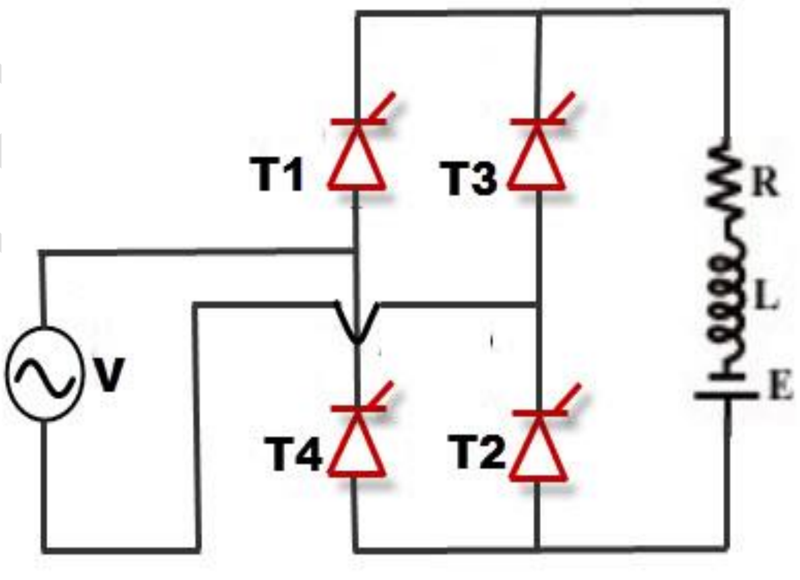


Figure 5.18 Full Wave Control Rectifiers Using Four Thyristors

References

1- **Electric Machinery Fundamentals.   Stephen J. Chapman.**

2- **Alternating Current Machines. Er. Rk. Rajput.**

3- **Electrical Technology. B.L. Thereja.**