UNIT – I

Electric Drives and Traction

Fundamentals of electric drive – Choice of an electric motor – applications of motors for particular services traction generator set, traction motors, power transformers – characteristic features of traction motor – Systems of railway electrification – electric braking – train movement and energy consumption – traction motor control – track equipment and collection gear

Fundamentals of Electric Drives

In most of the industrial and domestic applications like rolling mills, paper mills, cement mills, transportation systems, machine tools, robots etc, the main requirement is the motion control

A drive consists of various systems combined together for the purpose of motion control or movement control. The drives which employs electric motors for motion control are known as Electrical Drives.

Drives may employ any of the prime movers. such as, diesel or petrol engines, gas or steam turbines, steam engines, hydraulic motors and electric motors, for supplying mechanical energy for motion control. Electrical drive employs electric motors for this purpose.

Requirements of an Electric Drive:

An electric drive should satisfy the following requirements

(i) stable operation should be assured.

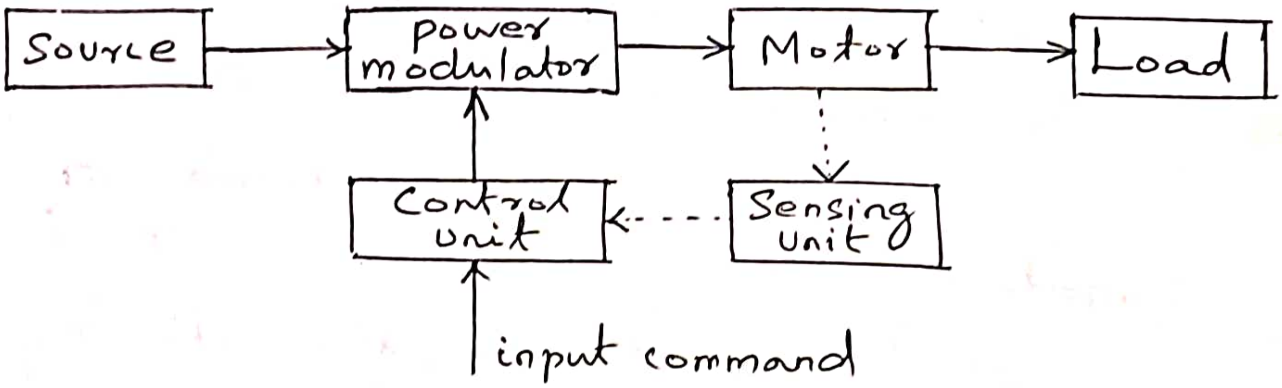
ii) The drive should have good transient response.

The speed-torque characteristic of the motor should be such that stable operation of the drive is assured in all the four quadrants over a wide range of speeds. The motor must have stable operation in the fourth quadrant.

The drive motor should also have a good transient response. In case of disturbance, the drive should return to its original operating condition very quickly.

General Electric drive System (Block diagram)

The electric drive system employing the principles of feedback control theory along with several components performing individual functions as shown in figure.



Electric drive - Block diagram

The block diagram of electric drive system is shown in figure. An electric drive motor drives the mechanical load. The power modulator or thyristor power converter. The converter has necessary controls to provide the required supply to the motor. Ex: Variable voltage variable frequency supply, if the drive motor is a.c motor.

Load is usually a machinery is designed to do a given task. Ex. fans, pumps, robots, washing machines, machine tools, trains etc

Components

Electrical drives have the following major components

1). Electrical motors and mechanical load
2). Power modulator 3). Source 4). Control unit. 5). Sensing unit.

Electrical motors

The possible forms of drive motors are

a) dc motors fed from dc supply
b) dc motors fed from ac supply
c) ac motors fed from ac supply

Commonly used drive motors are,

DC motors:- shunt motor, series motor, compound motor and permanent magnet motor.

AC motors - Induction motors
- Squirrel cage
- wound rotor
- linear

Synchronous motor
- wound field
- Permanent magnet

Brushless dc motors, stepper motor and switched reluctance motors are also be used.

Sources

In India single phase and three phase 50Hz a.c supply is available. Very low power drives are generally fed from single phase source. Other drives are powered from 3 phase source. Low and medium power motors are fed from 400V supply. For higher ratings, motors may be rated at 3.3KV, 6.6KV, 11KV.

DC drives, d.c supply is obtained from converters. Some drives are powered from a battery, battery voltage may be 24V, 48V and 110V d.c.

Power modulator ~~of power modulator~~

Functions of power modulator

i). Modulates flow of power from the source to the motor.

ii) During transient operations, such as starting, braking and speed reversal, it restricts source and motor currents within permissible values

iii) Converts electrical source (a.c to dc) in the form suitable to the motor.

iv). Selects the mode of operation of the motor. ie motoring or braking.

Power modulator may be ac-dc converters, ac regulators, choppers or dc-dc converters, Inverters, cyclo-converters. Some drives may employ more than one of these modulators.

Control unit

Controls for a power modulator are provided in the control unit. Nature of the control unit for a particular drive depends on the power modulator that is used.

Sensing Unit

Sensing unit has different sensors. They sense the ~~variable~~ different parameters of motors, like speed, current, voltage, temperature etc. The sensed signals are sent to the control unit.

Advantages of Electric Drives

i). Drives have flexible control characteristics

ii) They are available in wide range of torque, speed and power

iii) Starting and braking is simple and easy to operate.

iv) Drives can be provided with automatic fault detection systems.

Choice of an electric motor (or drive)

Selection of motor depends upon the following factors

i) Nature of electric supply

Which type of source, whether a.c or pure d.c or rectified a.c supply is to be used for motor. Magnitude of voltage, voltage fluctuations, powerfactor or harmonics also considered.

ii) Nature of the Drive

Whether motor is to drive individual machines or a group of machines

iii) Nature of load

Whether the load requires light or heavy starting torque.

Whether load torque increases with speed or remains constant.

Whether load has heavy inertia which may require long starting time.

iv). Electrical characteristics

i). Starting characteristics
ii) Running characteristic
iii) Braking characteristic iv) Speed control.

v). <u>Size and rating of motors</u>

Whether motor is to run continuously, intermittently or on a variable load cycle.

Whether overload capacity and pull out torque are sufficient

vi) <u>Mechanical considerations</u>

a). Type of enclosures

b). Type of bearings

c). Transmission of drive

d). Noise level.

vii) <u>Cost</u>

a). Capital cost

b). running cost

viii) <u>Other factors</u>

a). maintenance needs

b) life

c) Space and weight restrictions

d) Environment and location

e). Reliability

These are the factors influencing the choice of electrical drives (motors).

Types of Electric Drives

1). Group drive
2). Individual drive
3) Multi-motor drive

Based on supply,

1). DC motors - D.C drives
2). AC motors - A.C drives

Applications of motors for particular services

Electric traction

For electric traction, DC series motors are used. D.C series motors and A.C series motors are used because they provide a high starting torque. Now a days three phase induction motors ~~also~~ are also used.

Steel rolling mills

These loads are taken as intermittent loads. They require frequent starting, stopping and reversing operation. Slip ring induction motor and DC series motor are used.

steel rolling mills

SCR controlled DC shunt motor is used because the drive motor is required to withstand severe and rapid ~~torque~~ torque and speed changes.

Lifts

For starting a lift, a high starting torque is required. D.C compound motors, AC slip ring induction motor or high torque Squirrel cage induction motor are used.

Pumps, blowers and compressors

Loads like pumps, blowers and compressors require a load torque of 1 to 1½ times of full load torque. For this purpose, induction motors and variable frequency, variable voltage inverters are required for the control of such motors.

House hold appliances

For use in domestic appliances such as mixers, vacuum cleaners, hand driven tools, blenders etc universal motors are used. Heaters, hair driers shaded pole motors are used. Washing machines, air conditioners, refrigerators, fans single phase induction motors are used.

Mines

For mining work, squirrel cage induction motors with star delta, auto transformer starters are used. When high starting torque is needed. slip ring induction motors are used.

Electric traction System

The locomotion in which the driving force is obtained from electric motors is called the Electric Traction System. Various systems of electric traction existing such as electric trains, trolley buses, diesel-electric vehicles and gas turbine electric vehicles.

Requirements of an ideal traction system:

i). The starting tractive effort should be high

ii) The wear on the track should be minimum

iii) The equipment should be capable of withstanding large temporary loads.

iv). Speed control should be easy

v). Pollution free

vi). There should be no interference to the communication lines running along the track lines.

vii) low initial and maintenance cost.

viii) The locomotive should be self-contained and able to run any route.

ix). Braking should be such that minimum wear is caused on the brake shoes.

x). It is possible the braking energy should be regenerated and returned to the supply.

i). <u>High starting torque</u>

A traction motor must have high starting torque, which is required to start the motor on load during the starting conditions in urban and suburban services.

ii). <u>Speed control</u>

The speed control of the traction motor must be simple and easy. This is necessary for the frequent starting and stopping of the motor in traction purpose.

iii) <u>Dynamic and regenerative braking</u>

Traction motors should be able to provide easy simple rheostatic and regenerative braking, so that system must have the capability of withstanding voltage fluctuations

iv). <u>Temperature</u>

The traction motor should have the capability of withstanding high temperatures during transient conditions.

v). <u>Overload capacity</u>

The traction motor should have the capability of withstanding high temperatures during transient conditions.

vi). <u>Parallel running</u>

In traction, more number of motors need to run in parallel to carry more load.

Therefore, the traction motor should have such speed-torque and current-torque characteristics and those motors may share the total load almost equally.

vii). Commutation

Traction motor should have the feature of better commutation to avoid the sparking at the brushes and commutator segments.

Types of traction motors

1). D.C series motor with pure DC or rectified DC
2). AC series motors
3). Repulsion motors
4). Three phase induction motors.
5). Linear induction motors

DC series motors

DC series motors are widely used in traction. A DC series motor has high starting torque and capability for high torque overloads.

With an increase in torque, the flux also increases. therefore for the same increase in torque, the increase in motor current is less compared to other motors. Thus during heavy torque overload, power overload on the source and thermal overloading of the motor are kept limited to reasonable values. The speed torque characteristic is also suitable for better sharing of loads between loads.

AC series motors

AC series motor due to its desirable speed torque characteristics is almost exclusively used in railway service. It is more convenient and more economical to transmit power and to transform voltage in AC systems. It is generally used in street railway cars and trolley coaches.

Three phase Induction Motors

The following are the important factors for induction motors are used in traction purpose,

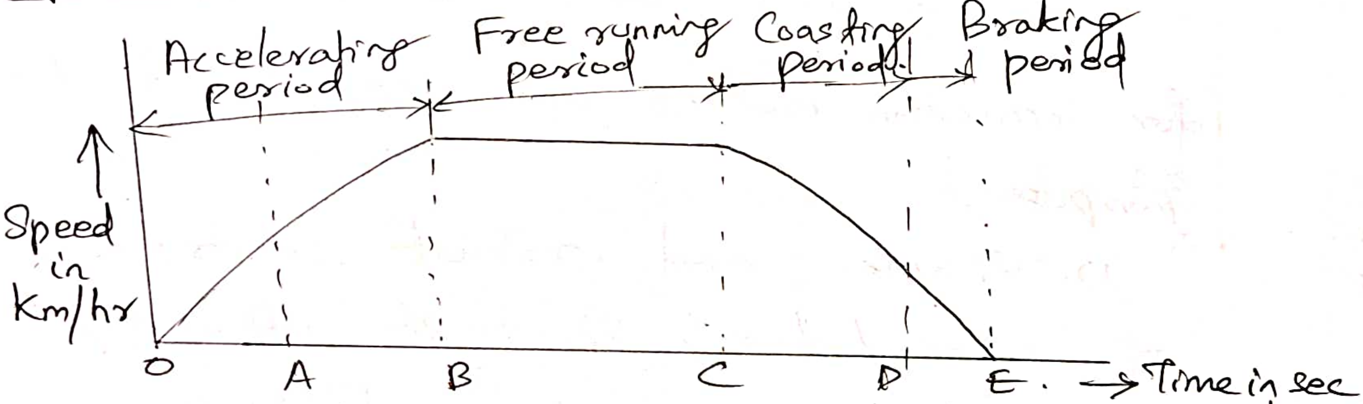
1). Simple and robust construction. 2). Absense of commutator. 3). High efficiency.
4). Simple regenerative braking.

With the development of thyristorised inverter circuits, it is possible to invert the supply and obtain a variable frequency which can be used for the 3 phase induction motor and a very smooth control can be obtained.

Linear Induction motors

It can be used on trolley cars, for internal transport in workshops. It can also be used as booster accelerator for moving heavy trains from rest or up the inclines. Linear induction motor has superiority over conventional motor for speed over 200 km/h. This motor forms excellent source of motive power for magnetically supended trains when conventional motor which depends for torque conversion, to linear tractive force upon the adhesive weight on driving wheels, rails.

Speed time curve for train movement



The curve drawn between speed in km/hr along Y axis and time in seconds along X axis is called Speed-Time curve. This speed time curve gives the complete information about the motion of the train.

Speed - Time curve consists of
1). Acceleration period 2). Free run or Constant speed period. 3). Coasting period 4). Retardation period.

Acceleration period.

It consists of two parts

a). Acceleration while notching up or constant acceleration.

b). Speed curve running or acceleration on speed.

During notching up period (OA) the current is maintained approximately constant and the voltage across the motor is gradually increased by cutting out the starting resistance.

During speed curve running (AB), the motor remains constant and current starts decreasing with the increase in speed.

Free run or Constant speed period (BC)

At the end of speed curve running at B, the train attains the maximum speed. During this period the train runs with constant speed attained at B and constant power is drawn.

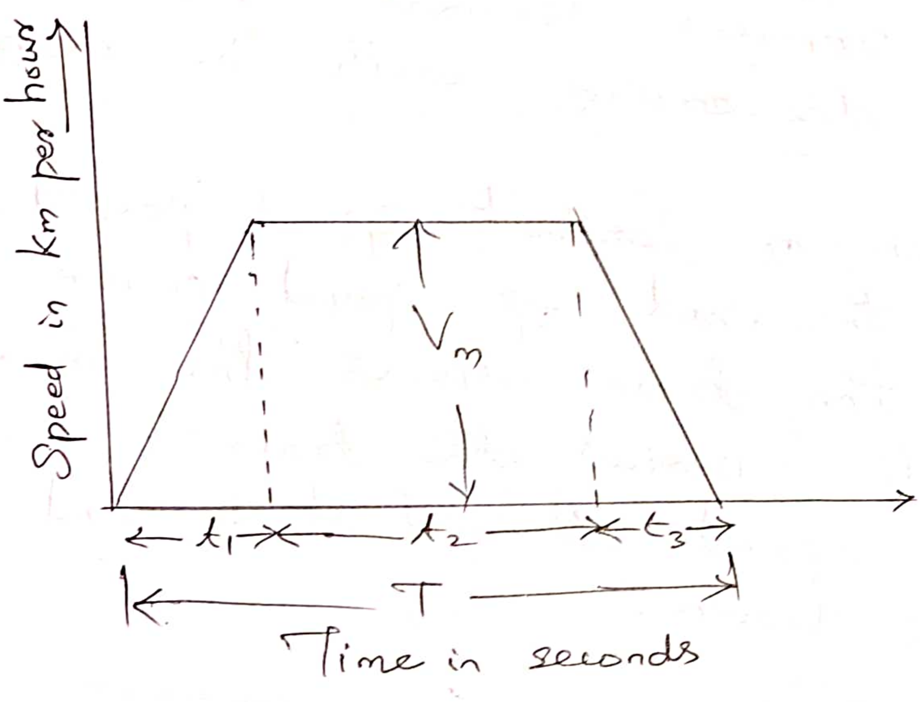
Coasting period (CD)

At the end of free running period at C, power supply to the cut off and the train is allowed to run under its own momentum. The speed starts decreasing on account of resistance to the motion of train. The rate of decrease of speed during coasting period is known as coasting retardation.

Retardation or Braking period (DE)

At the end of coasting period, at D, the brakes are applied to bring the train to rest. During this period speed rapidly decreases and finally to zero.

Trapezoidal Speed-Time curve



Let $\alpha \rightarrow$ Acceleration in km/hr/sec.

$\beta \rightarrow$ retardation km/hr/sec

V_c or $V_m \rightarrow$ Crest or maximum speed km/hr

$T \rightarrow$ Total time of run in seconds

D or S $\rightarrow$ distance between stops.

Time for acceleration $t_1 = \frac{V_c}{\alpha}$ sec.

Time for retardation $t_3 = \frac{V_c}{\beta}$ sec.

Time for free running $t_2 = T - (t_1 + t_3)$

$$= T - \left(\frac{V_c}{\alpha} + \frac{V_c}{\beta}\right) \text{ sec.}$$

Area of trapezoidal curve gives the total distance travelled by train

$$D = \frac{V_c\left(\frac{t_1}{2} + t_2 + \frac{t_3}{2}\right)}{3600}$$

Total distance of run in km,

D = Distance Travelled during acceleration + distance travelled during free run + distance travelled during braking

$$D = \frac{1}{2} V_c \frac{t_1}{3600} + V_c \frac{t_2}{3600} + \frac{1}{2} V_c \frac{t_3}{3600}$$

substituting $t_1 = \frac{V_c}{\alpha}$, $t_3 = \frac{V_c}{\beta}$, $t_2 = T - \left(\frac{V_c}{\alpha} + \frac{V_c}{\beta}\right)$

$$D = \frac{V_c^2}{7200\,\alpha} + \frac{V_c}{3600}\left[T - \left(\frac{V_c}{\alpha} + \frac{V_c}{\beta}\right)\right] + \frac{V_c^2}{7200\,\beta}$$

$$D = \frac{V_c T}{3600} - \frac{V_c^2}{7200\,\alpha} - \frac{V_c^2}{7200\,\beta}$$

$$D = \frac{V_c T}{3600} - \frac{V_c^2}{3600}\left[\frac{1}{2\alpha} + \frac{1}{2\beta}\right]$$

converting into Quadratic Equation form,

$$\frac{V_c^2}{3600}\left[\frac{1}{2\alpha} + \frac{1}{2\beta}\right] - \frac{V_c T}{3600} + D = 0$$

substituting $\frac{1}{2\alpha} + \frac{1}{2\beta} = k$, we get

$$kV_c^2 - V_c T + 3600\,D = 0$$

or

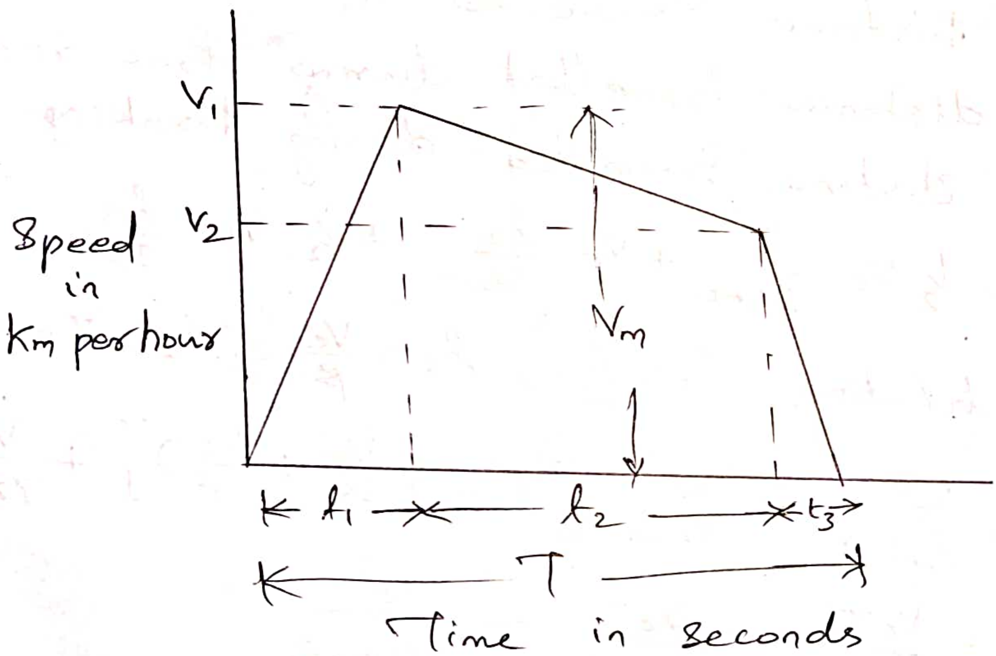
$$V_c = \frac{T \pm \sqrt{T^2 - 4 \times k \times 3600 \times D}}{2 \times k}$$

$$V_c = \frac{T}{2k} - \sqrt{\frac{T^2}{4k^2} - \frac{3600\,D}{k}}$$

If the +ve sign is used, the value of crest speed is very high which is not possible in practice. Hence -ve sign is used.

$$V_c = \frac{T}{2k} - \sqrt{\frac{T^2}{4k^2} - \frac{3600\,D}{k}}$$

Quadrilateral speed-time curve



α - acceleration in km/hr/sec

β_c - coasting retardation in km/hr/sec

β - braking retardation in km/hr/sec

V_1 - maximum speed at the end of the acceleration in km/hr

V_2 - Speed at the end of coasting in km/hr

Time for acceleration, $t_1 = \frac{V_1}{\alpha}$ sec

Time for coasting, $t_2 = \frac{V_1 - V_2}{\beta_c}$ sec

Time for braking, $t_3 = \frac{V_2}{\beta}$ sec

Total distance of run in km,

D = Distance travelled during acceleration + distance travelled during Coasting + distance travelled during retardation

$$D = \frac{1}{2} V_1 \frac{t_1}{3600} + \frac{V_1 + V_2}{2} \times \frac{t_2}{3600} + \frac{1}{2} V_2 \frac{t_3}{3600}$$

$$= \frac{V_1 t_1}{7200} + \frac{V_1 t_2}{7200} + \frac{V_2 t_2}{7200} + \frac{V_2 t_3}{7200}$$

$$= \frac{V_1}{7200}(t_1 + t_2) + \frac{V_2}{7200}(t_2 + t_3)$$

$\therefore T = t_1 + t_2 + t_3$

$$D = \frac{V_1}{7200}(T - t_3) + \frac{V_2}{7200}(T - t_1)$$

$$= \frac{T}{7200}(V_1 + V_2) - \frac{V_1 t_3}{7200} - \frac{V_2 t_1}{7200}$$

$$= \frac{T}{7200}(V_1 + V_2) - \frac{V_1}{7200} \times \frac{V_2}{\beta} - \frac{V_2}{7200} \times \frac{V_1}{\alpha}$$

$$= \frac{T}{7200}(V_1+V_2) - \frac{V_1 V_2}{7200 \times \beta} - \frac{V_1 V_2}{7200\,\alpha}$$

$$D = \frac{1}{7200}\left[T(V_1+V_2) - V_1 V_2\left(\tfrac{1}{\alpha}+\tfrac{1}{\beta}\right)\right]$$

We have $V_2 = V_1 - \beta_c t_2$

$$= V_1 \; \beta_c \;(T - t_1 - t_3)$$

$$= V_1 \; \beta_c \;\left(T - \frac{V_1}{\alpha} - \frac{V_2}{\beta}\right)$$

$$V_2 - V_2 \frac{\beta_c}{\beta} = V_1 - \beta_c\left(T - \frac{V_1}{\alpha}\right)$$

$$V_2 = \frac{V_1 - \beta_c T + \frac{\beta_c}{\alpha} V_1}{1 - \frac{\beta_c}{\beta}}.$$

Problem

A train runs with an average speed of 40 kmph. Distance between stations is 2 km. Values of acceleration and retardations are 1.5 kmphs and 2.5 kmphps respectively. Find the maximum speed of train assuming trapezoidal speed-time curve.

Solution:

Acceleration $\alpha = 1.5$ km.p.h.p.s

Retardation $\beta = 2.5$ km p.h.p.s

Distance of run S (or) D = 2 km.

Average speed $V_a = 40$ km.p.h

Time of run $T = \frac{D}{V_a} \times 3600 = \frac{2}{40} \times 3600$

$= 180$ seconds.

$$K = \frac{1}{2\alpha} + \frac{1}{2\beta} = \frac{\alpha/\beta}{\alpha+\beta} = \frac{1.5+2.5}{1.5 \times 2.5} = 1/06$$

$= 0.533$

Maximum or crest speed,

$$V_c = \frac{T}{2K} - \sqrt{\frac{T^2}{4K^2} - \frac{3600\,D}{K}}$$

$$= \frac{180}{2\times 0.533} - \sqrt{\frac{180^2}{4\times 0.533^2} - \frac{3600\times 2}{0.533}}$$

$= 46.36$ km p.h

A train is required to run between two stations 1.8 kms apart at an average speed of 45 km/hr. The run is to be made into quadrilateral speed-time curve. If the maximum speed is to be limited to 65 km/hr, acceleration is 3 km/hr/sec, coasting retardation 0.2 km/hr/sec and braking retardation 3 km/hr/sec. Determine the duration of acceleration, coasting and braking periods.

Solution.

$V_1 = 65$ km/hr. $D = 1.8$ km.

$V_a = 45$ km/hr

$\alpha = 3$ km/hr/sec

$\beta = 3$ km/hr/sec

$\beta_c = 0.2$ km/hr/sec.

$$t_1 = \frac{V_1}{\alpha} = \frac{65}{3} = 21.66\text{ sec.}$$

$$T = \frac{D\times 3600}{V_a} = \frac{1.8\times 3600}{45}$$

$= 144$ sec.

$$V_2 = \beta\left[V_1\left[1+\left(\beta/\alpha\right)\right] - \beta_c T\right] \times \frac{1}{\beta - \beta_c}.$$

$$V_2 = 3\left[65\left[1+\left(3/3\right)\right] - 0.2\times 144\right] - \frac{1}{(3-0.2)}$$

$$= 43.42 \text{ km/hr}$$

$$t_2 = \frac{V_1 - V_2}{\beta_c} = \frac{65 - 43.42}{0.2}$$

$$= 102.9 \text{ sec.}$$

$$t_3 = T - (t_1 + t_2) = 144 - (21.66 + 102.9)$$

$$= 19.35 \text{ sec.}$$

Systems of Railway Electrification

Traction electrification systems are

a). DC system

b). AC system — Single phase / Three phase

c). Composite system — Single phase AC–DC / Single phase–Three phase

DC system

In this system energy is obtained from the substations which consists of transformers and converting equipments like SCRs. The substations receive a.c power from a 3 phase high voltage (33 to 110 kV) transmission lines and convert it into d.c either by rotary converters or by Mercury Arc rectifiers or Thyristor converters with suitable transformation ratio. In this system D.C series motors are employed, compound motor are also employed.

Single phase AC System

In this system, a.c series motors are used for getting the necessary motive power. The operating voltage is between 300V to 400V at frequency of 25 Hz or 16.67 Hz. The energy is obtained at high voltage in the range of 15kV to 25kV and the frequency is 50 Hz.

Three phase AC System

In this system 3 phase induction motors operating at 3000 V to 3600V and normal frequency. The substations receive power from high voltage transmission lines at power frequency and step down the voltage and frequency if desired. This system is employed in hilly areas, where output required is high and regeneration on large scale is possible.

Composite system

The advantages of ac system and dc system are grouped together in this system.

The 1ϕ ac system is preferable from the view point of the distribution and contact wire system. The two types of composite systems are as follows.

1ϕ AC to DC System

In this system, the advantages of the two systems are combined together by employing high voltage 1ϕ a.c system for overhead distribution and d.c series motor for the necessary drive so that high efficiency is obtained together with the desirable characteristics of dc series motors.

1ϕ – 3ϕ System (or) KANDO System

In this system, single phase high voltage ac system is employed for distribution purpose and three induction motors for getting the necessary motive power. The voltage used for distribution network is 15kV, 50Hz frequency. The locomotive carries a phase converter for converting 1ϕ supply into 3ϕ supply at low frequency. The development of SCR used as inverter has made possible to get variable low frequency supply at which induction motor develops high starting torque.

3). Plugging region $(1 \leq s \leq 2)$

In this region, the slip becomes greater than unity. So the motor rotates in the opposite direction of rotating magnetic field. The direction of rotating magnetic field is changed by changing the phase sequence. The machine is quickly come to stop, if the supply is not disconnected under this condition. This method of braking of induction motor is known as plugging.

Braking of Motors

Braking includes rapid stopping of the electric motor, holding the motor shaft to specific position and maintaining the speed to a desired value of preventing the motor from over speeding. Generally two types of braking methods namely,

1). Mechanical braking 2). Electric braking.

Mechanical braking

In mechanical braking, the frictional force between the rotating parts and break drum provide the required brake.

Mechanical equipements such as brake linings, brake shoes and brake drums are required.

Electric braking

In electric braking, the motor is made to work as generator. So it produces a negative slip and negative torque. This is achieved by suitably changing the electrical connections of the motor. Generally there are three types of electrical braking methods,

1). Regenerative braking
2). Dynamic or Rheostatic braking.
3). Plugging or counter current or reverse current braking.

Regenerative braking of D.C motors.

D.C shunt motor

In regenerative braking operation the D.C shunt motor acts as a D.C shunt generator. The motor speed is greater than synchronous speed. Mechanical energy is converted into electrical energy. Part of electrical energy is returned to supply.

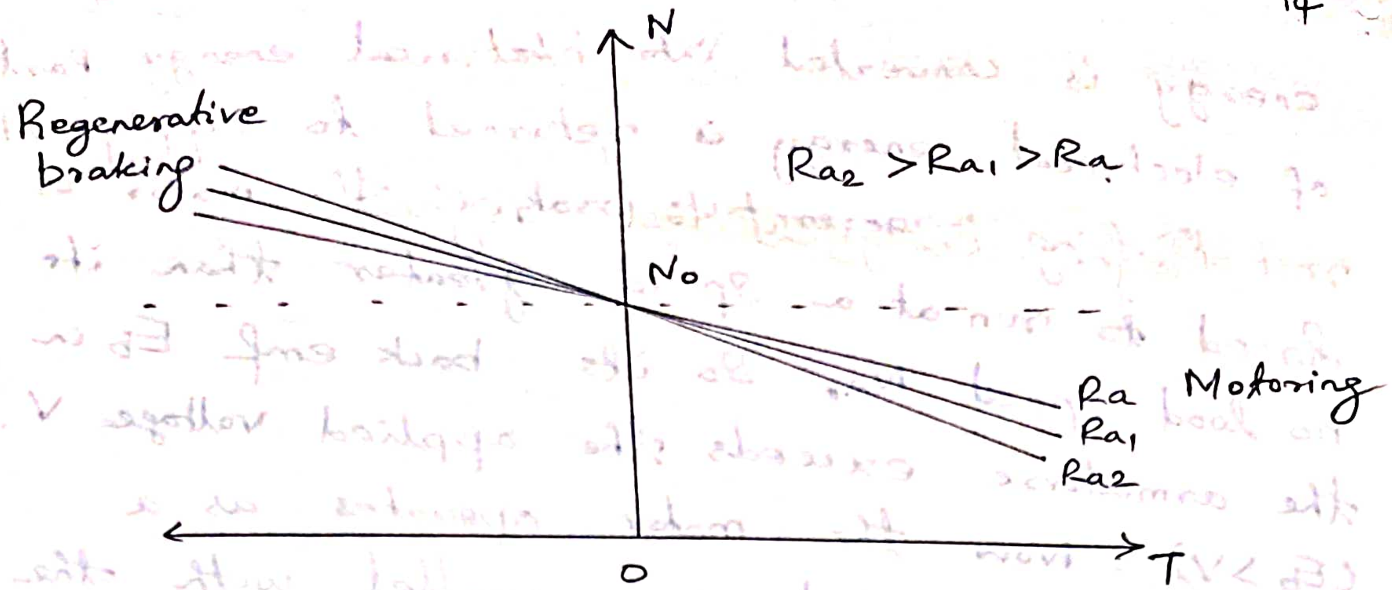
During regenerative braking the motor is forced to run at a speed greater than its no load speed N_o. So its back emf E_b in the armature exceeds the applied voltage V. ($E_b > V$). Now the motor operates as a generator connected in parallel with the supply and the direction of the armature current also reverses. So that energy is returned to the supply mains.

$$I_a = \frac{V - E_b}{R_a}$$

when $E_b > V$, $$I_a = -\frac{(V - E_b)}{R_a}$$

When the reversal of the direction of armature current the motor torque also reverses. So braking torque is developed.

The speed-torque characteristics of dc shunt motor under regenerative braking condition is shown in figure.



When the armature circuit resistance Ra is higher, the speed at which the motor run for a given braking ~~torque~~ also higher.

Lowering of hoist and down hill direction of electric traction (train) are the examples of regenerative braking.

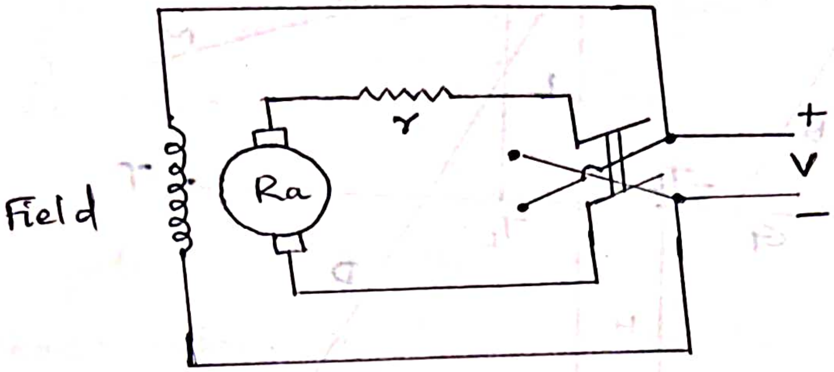
D.C Series motor

Regenerative is not possible in d.c series motor. Because the reversal of direction of armature current, the direction of field excitation also reverses.

So some special arrangements are used, and regenerative braking is used in traction motors.

Plugging (or) Counter current braking (or) reverse current braking.

D.C shunt motor



The circuit diagram for plugging of d.c shunt motor is shown in figure. It is also known as counter-current braking or reverse current braking.

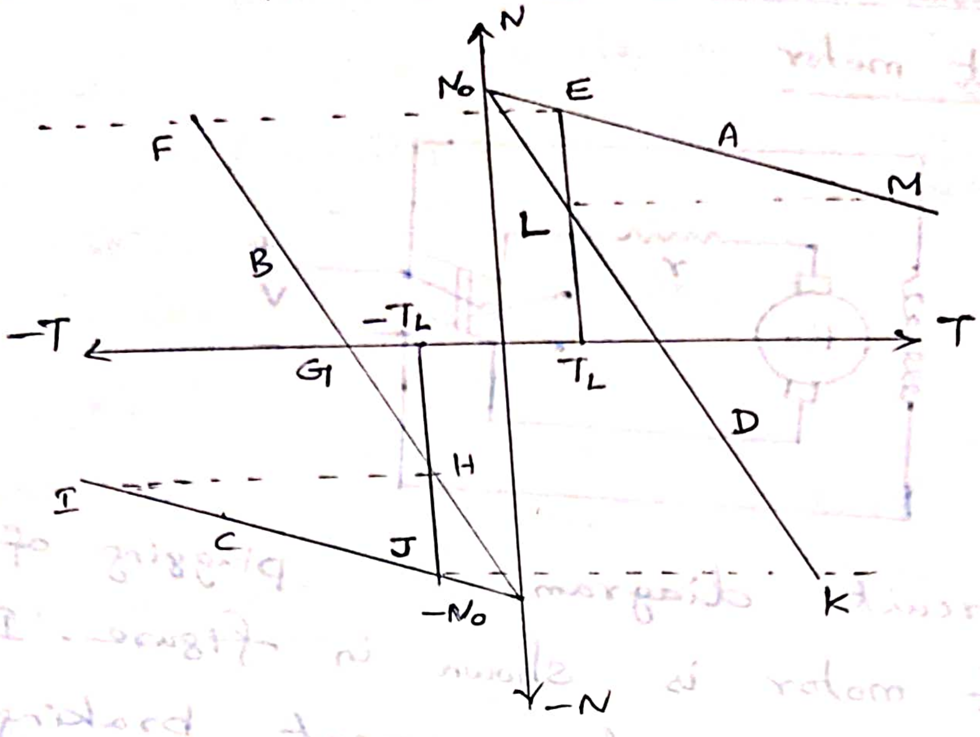
Plugging occurs when the motor windings are connected for reverse direction of rotation, when armature is still rotating in the forward direction. For plugging the motor reversal may be done by reversing the polarity the applied voltage either to the armature or to the field winding.

If the input voltage V is reversed then,

$$V = E_b + I_a R_a \quad , \quad I_a = \frac{V - E_b}{R_a}$$

if $V = -V$, $\quad -V = E_b + I_a R_a \quad , \quad I_a = \frac{-(V+E_b)}{R_a}$

Reversal of polarity of armature current produces a plugging torque.

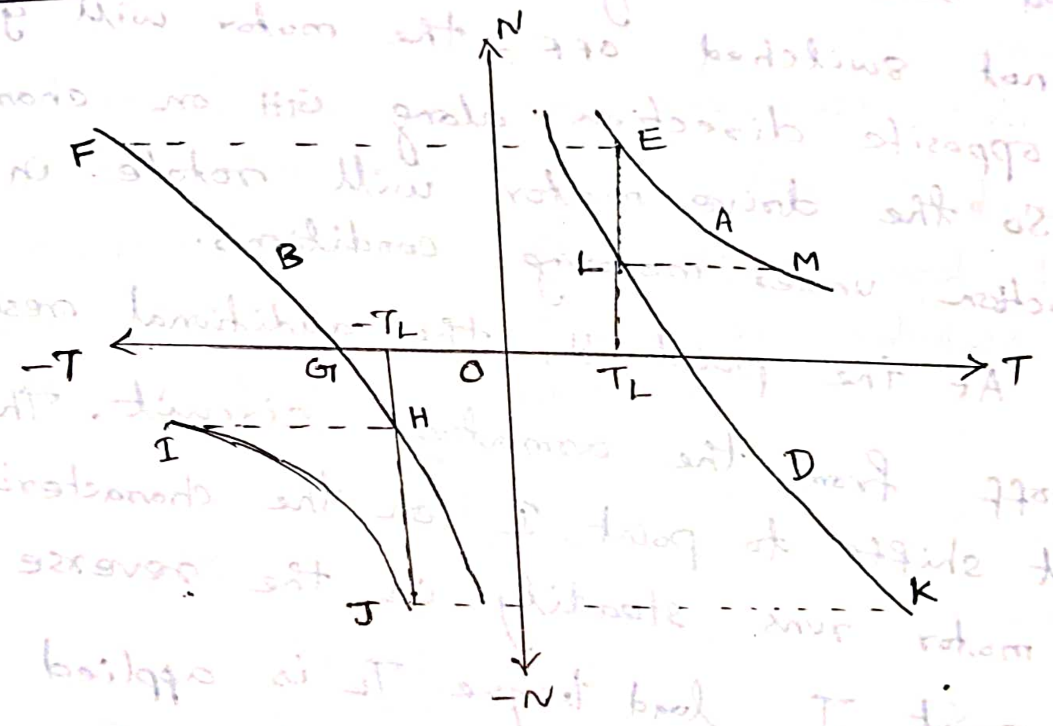


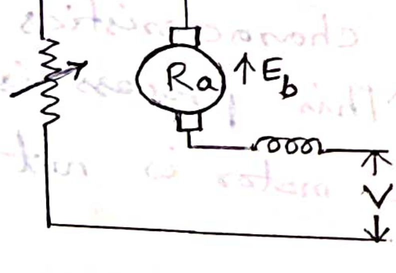
The speed - Torque characteristics of d.c shunt motor under plugging is shown in figure. The operating point E shifts to point F, on characteristic B. The braking torque developed, the motor accelerates along characteristics B until the motor stops at G.

When the reversal of rotation is not required the supply must be switched OFF. The motor speed becomes nearly equal to zero. If the supply is not switched OFF, the motor will gain speed in opposite direction along GH on characteristics B. So the drive motor will rotate in the reverse direction under motoring conditions.

At the point H, the additional resistances are cut off from the armature circuit. The operating point shifts to point I on the characteristics C. The motor runs steadily in the reverse direction. At point J load torque T_L is applied and the motor accelerates along the charactesistics D and runs in forword direction. This process is repeated again and again if the motor is not switched off after plugging.

D.C Series motor





The circuit diagram and speed-torque characteristics of d.c series motor under plugging is shown in figure.

For d.c series motor plugging can be done by reversing the polarity of the applied voltage to the armature. But current flowing in the field winding remains in same direction.

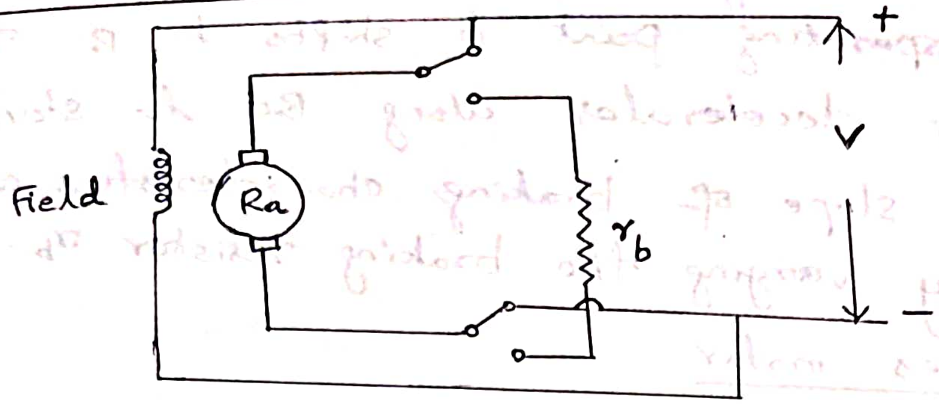
The operating point E shifts to point F on characteristics B. Braking torque developed, the motor accelerates along characteristics B until the motor stops at G.

When the reversal of rotation is not required the supply must be switched OFF. The motor speed becomes nearly equal to zero. If the supply is not switched OFF, the motor will gain speed in opposite direction along GH on characteristics B. So the drive motor will rotate in the reverse direction under motoring conditions.

At the point H, the additional resistances are cut off from the armature circuit. The operating point shifts to point I on the characteristics C. The motor runs steadily in the reverse direction. At point J load torque T_L is applied and the motor accelerates along the characteristics D and runs in forward direction. This process is repeated again and again if the motor is not switched off after plugging.

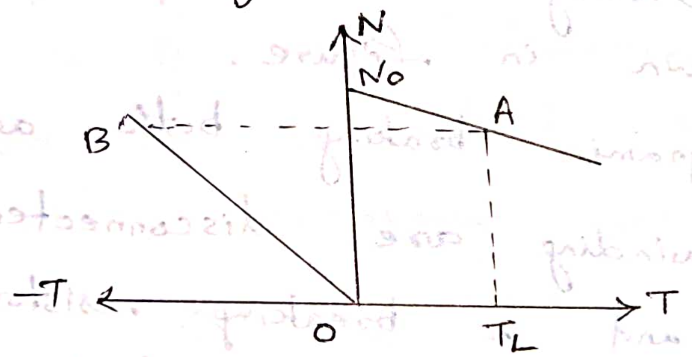
Dynamic or Rheostatic braking

DC shunt motor



The circuit diagram for dynamic braking of d.c shunt motor is shown in figure.

Dynamic braking can be done by disconnecting the armature from supply and connecting an external resistance across the armature terminals. This method is also called rheostatic braking. The field winding is left connected across the supply and it is undisturbed. The braking effect is controlled by varying the braking resistance r_b.

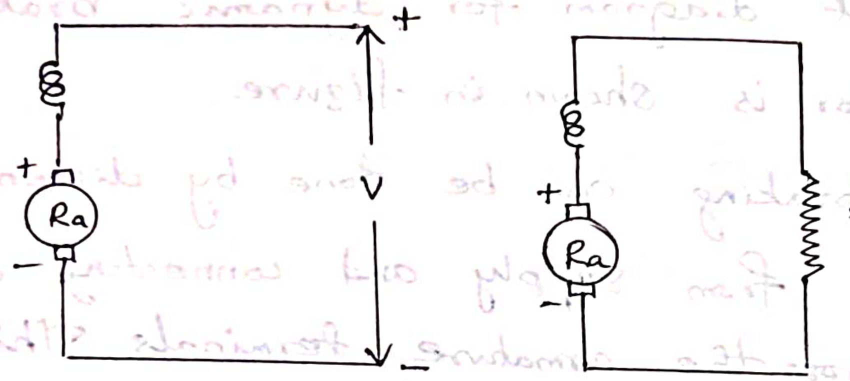


The speed-torque characteristics of a d.c shunt motor under dynamic braking condition is shown in figure.

It will be a straight line as shown in figure. When dynamic braking is applied for a given load torque T_L, the operating point A shifts to B. The d.c motor decelerates along BO to standstill.

The slope of braking characteristics can be controlled by varying the braking resistor r_b.

<u>D.C Series motor</u>



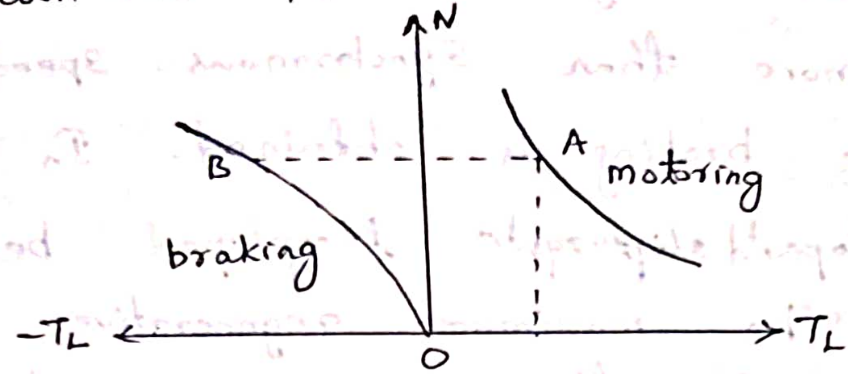
Motoring (normal) condition

Dynamic braking Condition

The circuit diagram for motoring condition and dynamic braking condition of d.c series motor are shown in figure.

During dynamic braking both armature and field winding are disconnected from the supply and a breaking resistor r_b is connected across them. The braking characteristics can be controlled by using breaking resistor.

The speed-torque characteristics of a d.c series motor under dynamic braking condition is shown in figure.



At normal condition, speed decreases when torque increases. When dynamic braking is applied for a given load torque T_L, the operating point A shifts to B. The dc series motor decelerates along BO to standstill.

Braking of induction motors

Regenerative braking

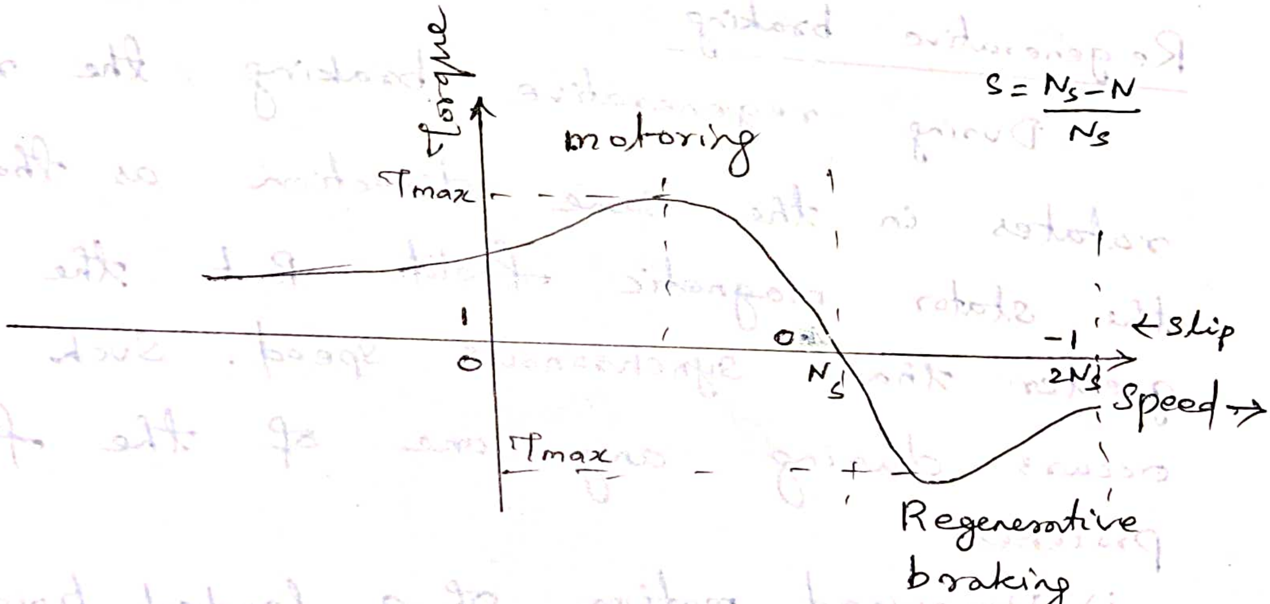
During regenerative braking the rotor rotates in the same direction as that of the stator magnetic field. But the speed greater than synchronous speed. Such state occurs during any one of the following processes.

i). Downward motion of a loaded hoisting mechanism.

ii) Downhill motion of an electric traction (train)

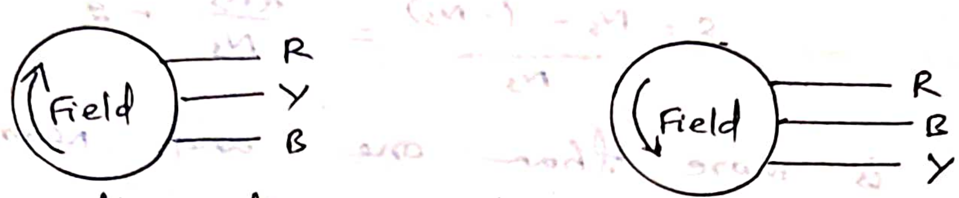
Under regenerative braking, the motor acts as an induction generator. The motor speed becomes more than synchronous speed and regenerative braking is obtained. In this case, the developed slip and torque becomes negative. The maximum regenerative braking torque is higher than maximum motor torque.

The induction generator generates electric power and this power is fed back to the supply. The speed-torque characteristics of the motor for regenerative braking is shown in figure.

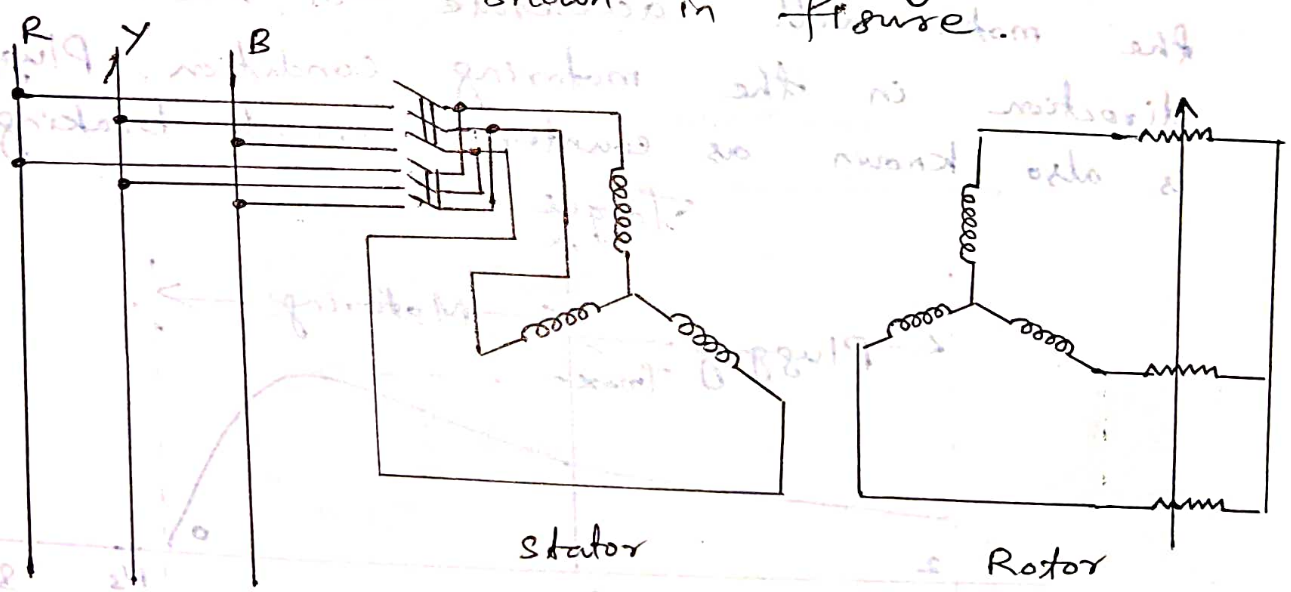


Plugging

Plugging or reverse current braking condition is done by reversing the direction of the field as shown in figure. The direction of rotation of the field in the air gap depends on the phase sequence of the stator windings.



When the three phase stator windings are connected in the RYB sequence, the airgap field rotates in one direction at synchronous speed. If the phase of the stator winding is changed to RBY, the field reverses its direction. It is done by interchanging the supply of any two terminals of the motor as shown in figure.



Thus the rotor and stator magnetic field rotates in opposite directions, slip of the motor is given by,

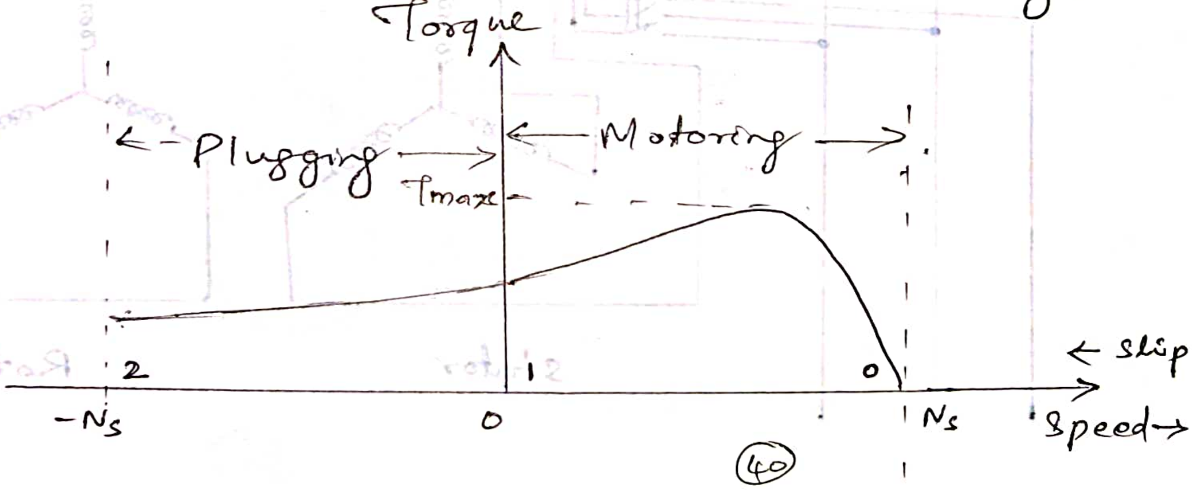
$$s = \frac{N_s - N}{N_s}$$

If $N = -N_s$,

$$s = \frac{N_s - (-N_s)}{N_s} = \frac{2N_s}{N_s} = 2$$

slip is more than one and nearly equal to 2.

The speed - torque characteristics of the motor during plugging is shown in figure. The direction of torque developed is reversed and the motor begins to slow down till its speed becomes zero. At this instant the motor is disconnected from the supply, otherwise the motor will accelerate in the reverse direction in the motoring condition. Plugging is also known as counter current braking.



Dynamic braking

There are two types of dynamic braking. They are,

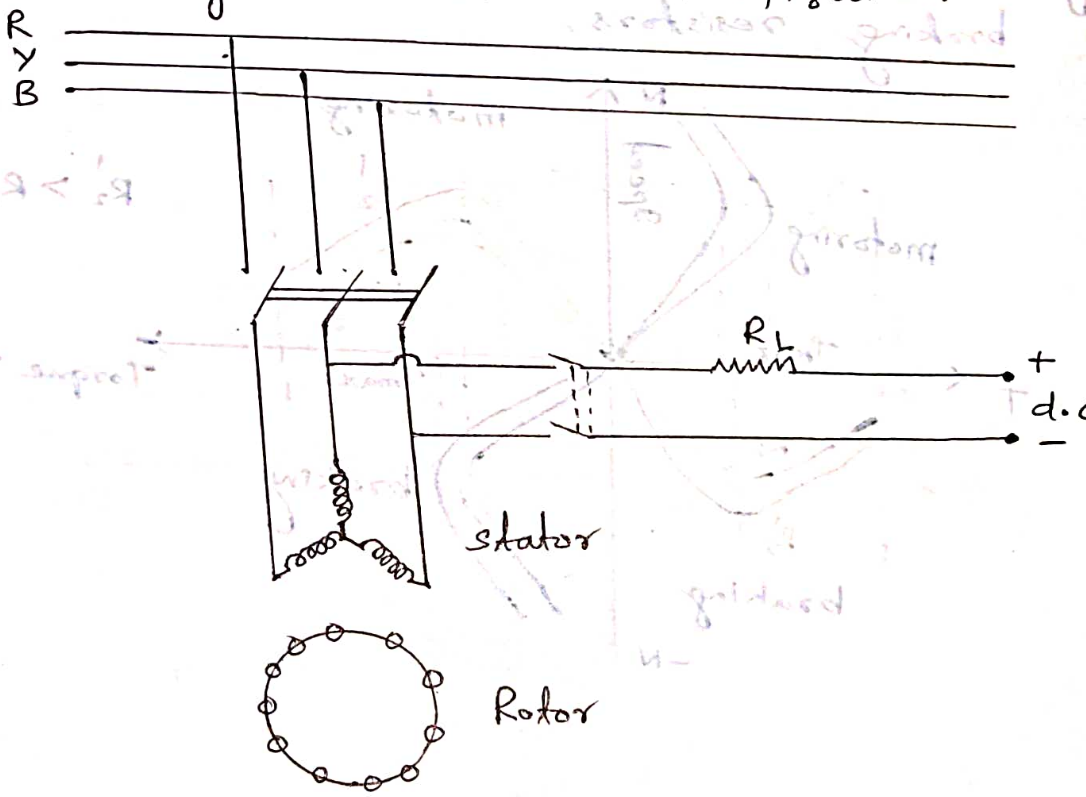
1). D.C dynamic braking.

2). A.c dynamic braking.

D.C dynamic braking

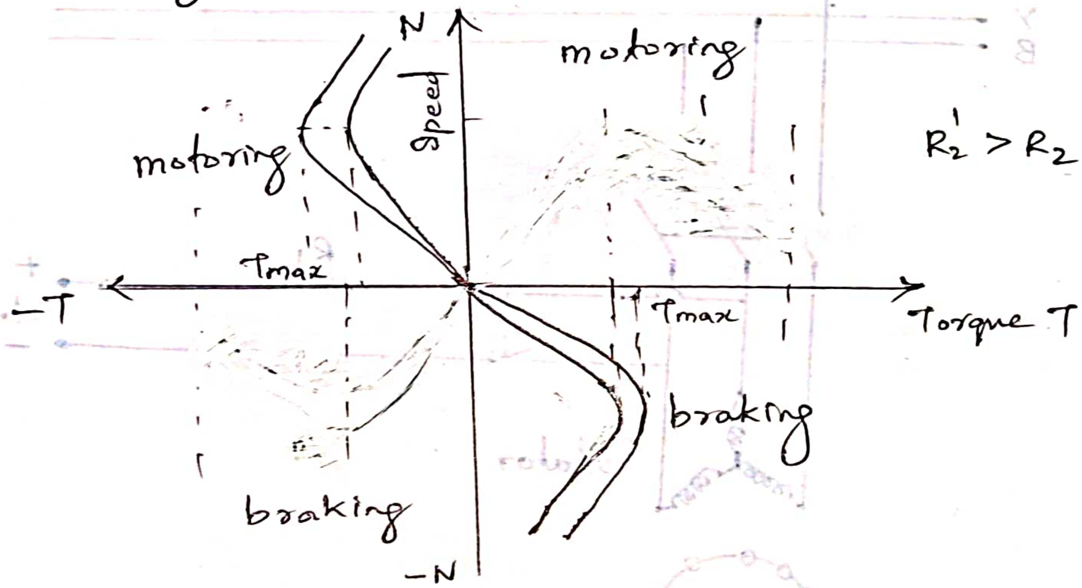
During dynamic braking of an induction motor, its ac supply is disconnected and a dc supply is connected to the two phases of stator winding.

The circuit diagram for feeding a d.c supply to the induction motor is shown in figure. A seperate d.c supply is fed to the stator winding as shown in figure.



A limiting resistor R_L is used in the circuit for controlling d.c excitation. For d.c supply. d.c source or rectifier is used. The d.c voltage producing a stationary magnetic field in the airgap. The rotor is continuously rotating due to stator magnetic field. Due d.c source, an emf is induced in the rotor conductors. That is opposite to the direction of motoring operation and produce braking torque.

The speed torque characteristics during dynamic braking is shown in figure. The braking characteristics can be controlled by using braking resistors.

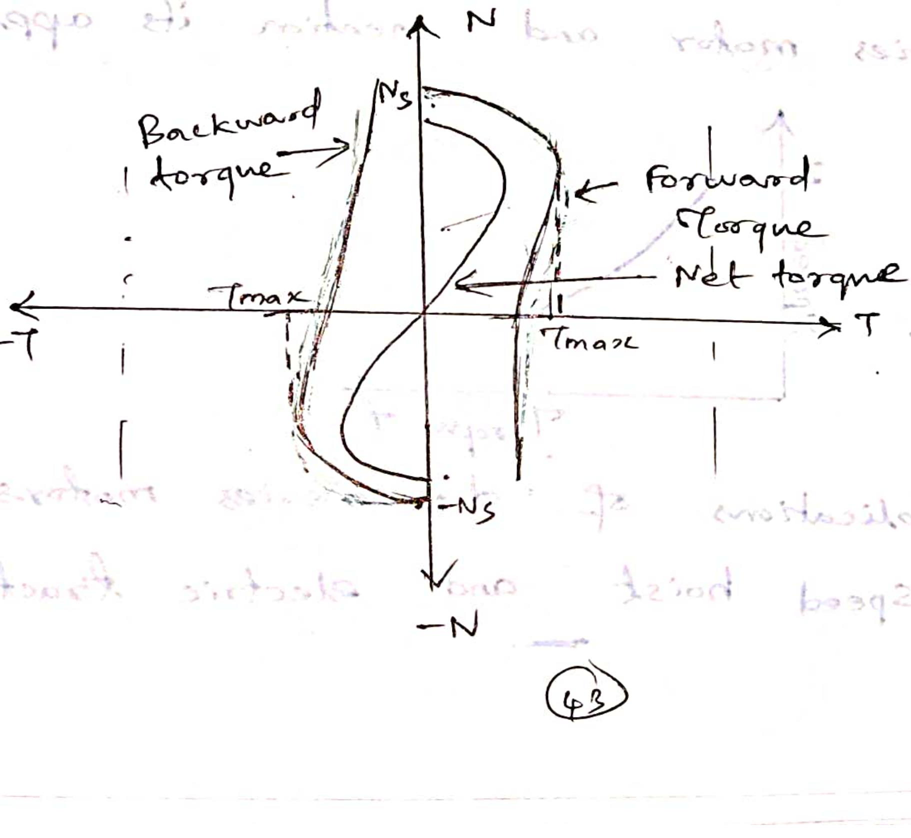


AC Rheostatic or AC dynamic braking

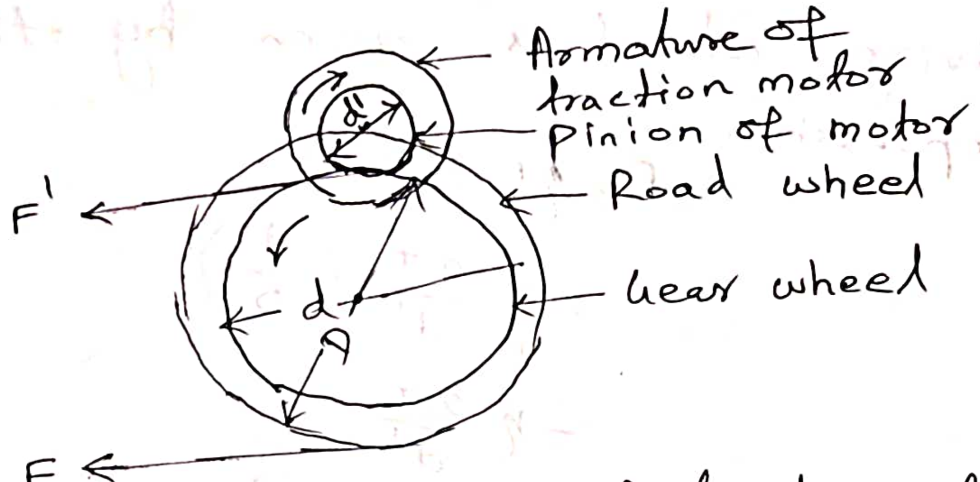
For a.c dynamic braking of an induction motor, its three phase a.c supply is disconnected and single phase ac supply is connected to stator windings.

Using revolving field theory, the torque produced by the forward field and backward field are in opposite direction. So net torque developed in a single phase induction motor is zero.

The speed – torque characteristics during AC dynamic braking is shown in figure. From this figure net torque of single phase induction motor becomes zero at little less than synchronous speed. In between this speed and the synchronous speed the developed net torque is negative.



Mechanics of Train movement



Transmission of tractive effort

The essential driving mechanism of an electric locomotive is shown in figure. The armature of the traction motor has a pinion diameter d' attached to it. The tractive effort at the edge of the pinion is transferred to the driving wheel by mean of a gear wheel.

Let the traction motor exert a torque T in Nm. Tractive effort at the edge of the pinion is given by the expression

$$T = F' \frac{d'}{2} \quad \text{or} \quad F' = \frac{2T}{d'}$$

Tractive effort transferred to the driving wheel is given by the expression

$$F = \eta F' \left(\frac{d}{D}\right)$$

$$= \eta \frac{2T}{d'} \cdot \left(\frac{d}{D}\right)$$

$$= \eta \frac{2T}{d'}$$

$$= \eta \, 2T \left(\frac{\gamma}{D}\right).$$

where d is the diameter of gear wheel in meters.

η is the efficiency of transmission

γ is gear ratio $= \frac{d}{d'}$.

The maximum frictional force between the driving wheel and the track $= \mu W$ where μ is the coefficient of adhesion betwen the driving wheel and the track.

<u>Adhesive weight (W)</u>

The total weight to be carried on the driving wheels is called the adhesive weight

Sliping will not take place unless tractive effort $F > \mu W$. For motion of train without slipping, tractive effort F should be less than or equal to μW but in no case greater than μW.

Co-efficient of Adhesion (μ)

The co-efficient of adhesion is defined as the ratio of tractive effort to slip the wheels and adhesive weight.

$$\mu = \frac{F}{W} = \frac{\text{Tractive effort to slip the wheels}}{\text{Adhesive weight}}$$

The normal value of μ with clean dry rails is 0.25 and with wet or greasy rails is 0.15 to 0.20 may be used.

Traction motor control

The control of traction motors is needed for

i). Starting without drawing excessive current from the supply

ii) Smooth acceleration without causing sudden shock so as to avoid damage to the couplings and inconvenience to the passengers.

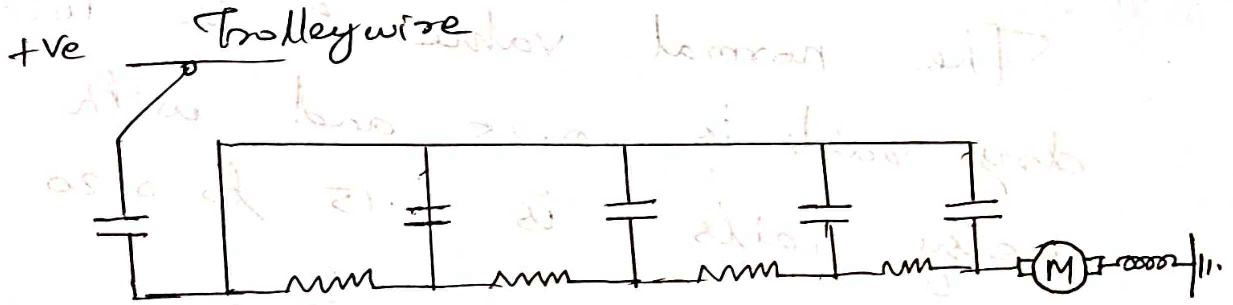
iii) Speed control as per requirement
iv) Providing rheostatic or regenerative braking

Speed control of DC series motors

Various methods for controlling the speed of dc series motors are

1). Rheostatic control
2). Series parallel control
3). Field control
4). Buck and Boost method
5). Metadyne control
6). Thyristor control.

Rheostatic control



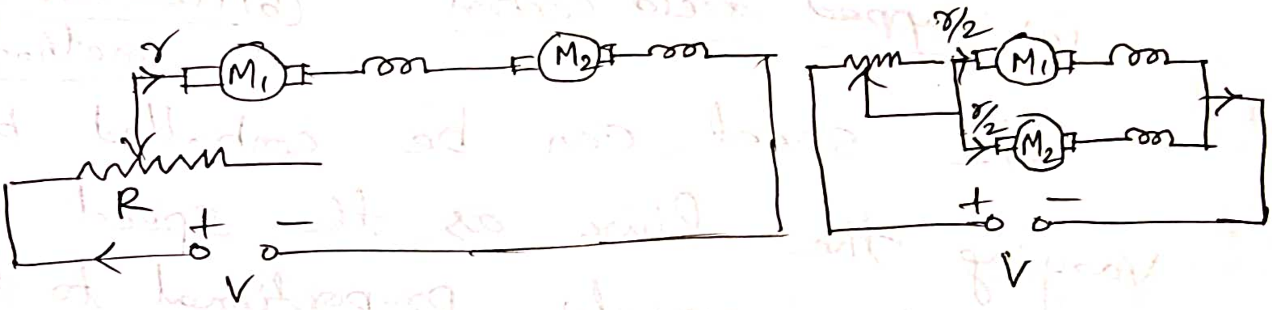
Basic traction motor circuit with rheostatic starting is shown in figure.

$$I = \frac{(V - E_b)}{R}$$

At the time of starting, the back emf is zero and the motor runs at higher speed. The external resistance is connected to its maximum such that the value of voltage drop across it with full load rated current is equal to line voltage.

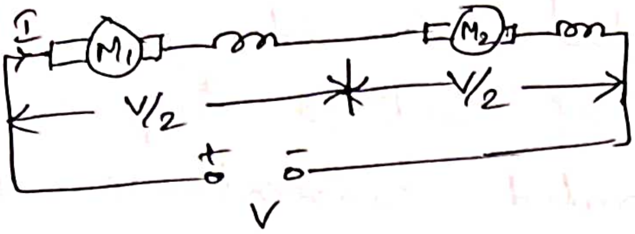
The resistors employed are designed for short time rating and not for continuous rating as they are required to carry current only during starting of the motors.

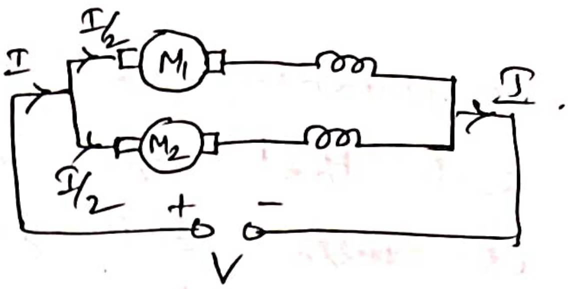
Series – parallel control



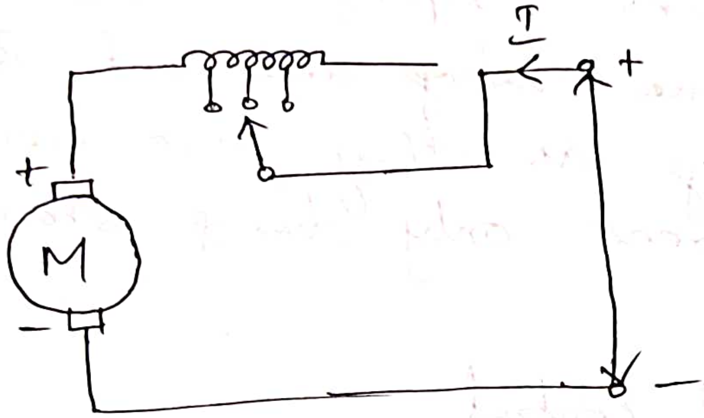
Series – Parallel control

Consider two motors are connected in series with each other at the time of starting and in parallel for full speed. The starting resistance is gradually cut out as the motor attains speed and finally the control resistance is totally removed. This is shown in figure

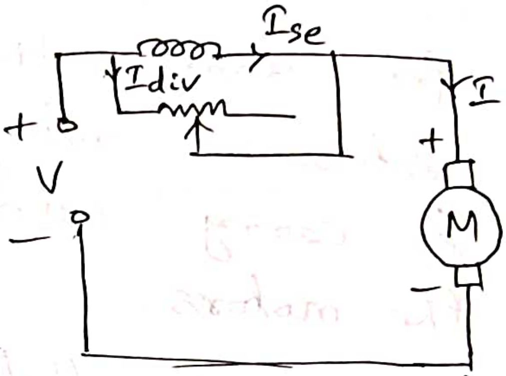




Field control



(a) Tapped field control



(b) Field diverter method

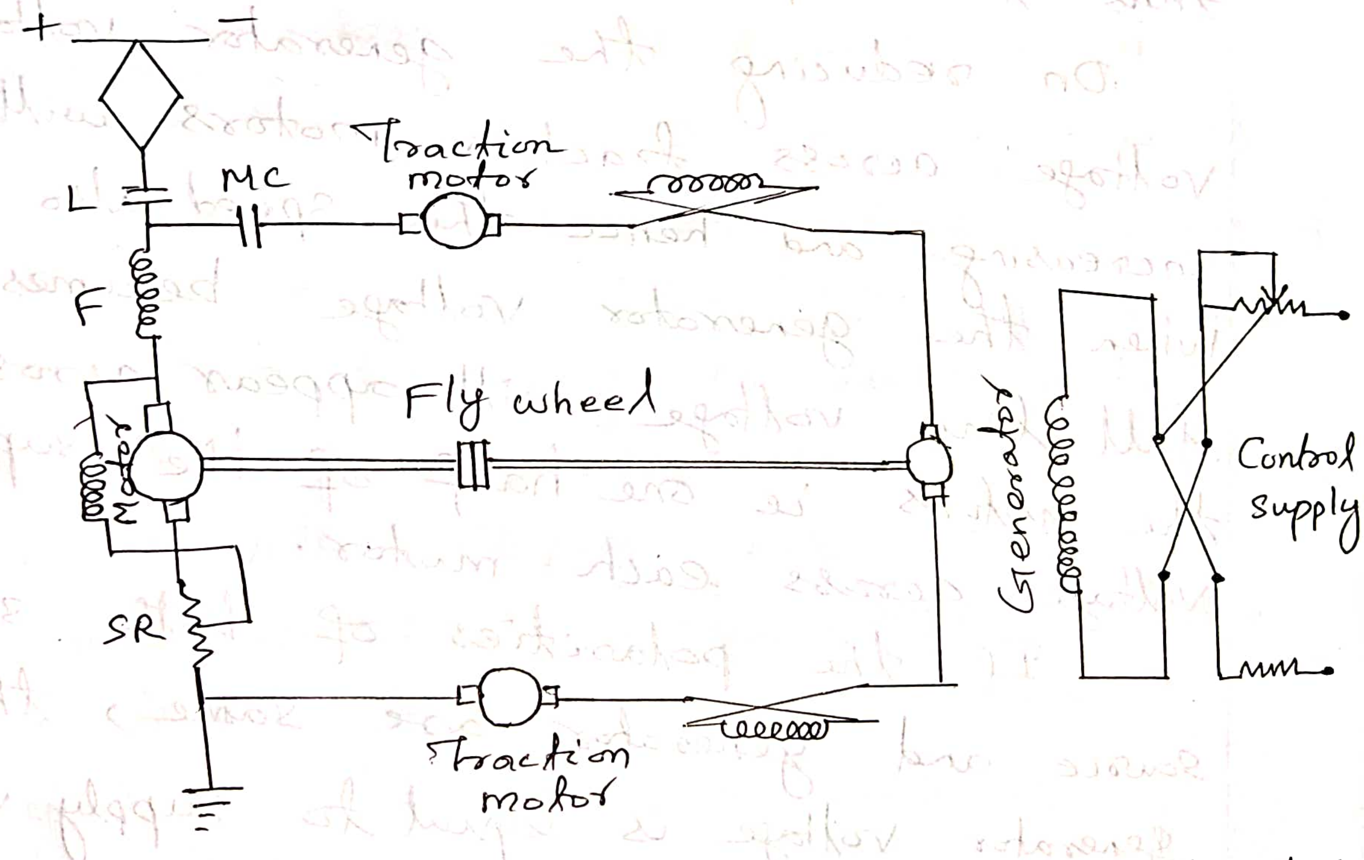
The speed can be controlled by varying the flux as the speed of the motor is inversely proportional to the flux.

In case of d.c series motor the flux can be varied either by,

- Connecting a variable resistance known as diverter in parallel with the series field winding (fig a)
- cutting out some of the series field turns. (fig b)

In both cases the flux can be only reduced and therefore this method is called field weakening method. By this method the speed can raised to 15% to 30% of normal speed. This method is not applied for starting purposes. The advantages of this method is that it increases the flexibility of train utility.

Buck and Boost method



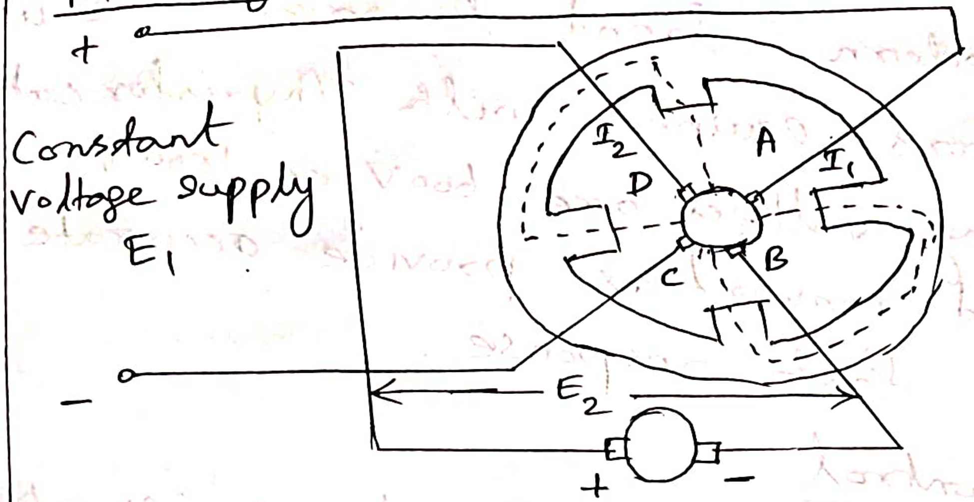
Buck and Boost method of speed control

In this method, the armatures of both the traction motor I and II and MG set are connected in series and the whole combination is connected across the supply as shown in figure. When the generator terminal voltage is equal to supply voltage in magnitude but of opposite polarity and main contactor MC is closed, the voltage across the traction motor is zero and thus their speed is also zero.

On reducing the generator voltage, voltage across traction motors will start increasing and hence the speed also increases. When the generator voltage becomes zero, full line voltage will appear across both the motors ie one half of the supply voltage across each motor.

If the polarities of both supply source and generator are same, the generator voltage is equal to supply voltage. By varying the excitation of the generator, the speed can be controlled.

Metadyne control



Metadyne converter consists of a 2 pole dc armature with two pairs of brushes and a 4 pole field magnet as shown in figure. One pair of brushes (say A and C) is connected across constant voltage d.c supply while the other pair (B and D) is connected to the load (normally d.c series motor).

The metadyne converter transforms the constant voltage supply into a constant current variable voltage supply to feed the load. This is more suitable for starting d.c traction motors.

Thyristor control

The modern trend towards the use of dc motors equiped with Thyristor control. The operating voltages are 600V or 1000 V. Thyristorised converters provide accurate control and fast response.

a). phase control

The acceleration of dc series motor is controlled by varying the voltage applied to the motors from very low value at start to the full value at high speed. Cycle selection method is mostly employed in addition to ordinary phase control methods. In this method, the required average voltage is obtained by accepting or rejecting a certain number of complete half cycles.

b) chopper control

In order to eliminate the power losses and provide infinitely variable speed control, can be used. These pulsed input voltages pulsed input voltages are obtained by utilizing a chopper controller.

Speed control of three phase motors

1). Rheostatic control

Metallic or liquid rheostats are inserted in the rotor circuit. Liquid rheostats are preferred as they have no inductance and the resistance can be cutout smoothly giving a uniform torque. During the starting period half the energy supplied is wasted in the starting resistances. This method is applied to light locomotives and motor coaches where energy consumption is of no importance.

2). Pole changing method

This is the simplest of the multi speed control methods. The winding on the stator may be so arranged that with different connections, different number of poles are available which give different speeds. The choice of number of poles is in the ratio of 2:1, 3:2 and 4:3

3). Cascade control

This method is employed for the two-speed goods locomotives (24 kmph and 50 kmph). This requires two motors have to be mechanically coupled together.

4). Combination of cascade and pole changing control

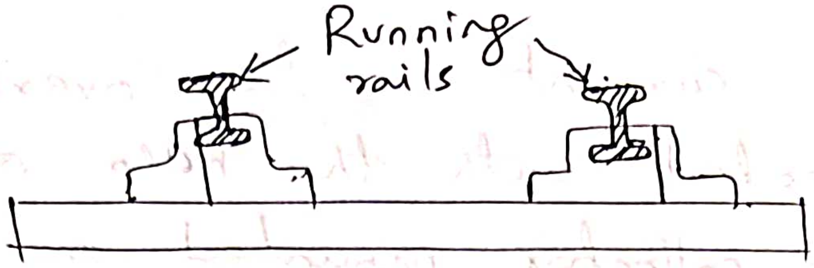
In this method, both the motors have the same number of poles but the number of poles can be changed. With equal number of poles on both, one speed is obtained and then more speeds are possible by pole changing.

Traction current collection system

These are mainly two systems of current collection for locomotives, tramsways or trolley buses namely

1). Conductor rail system and
2). Overhead system

Conductor rail system



Conductor rail system is employed at 600 V for suburban services. In this system, current is supplied to the electrically operated vehicles either through one rail conductor or through two rail conductors. In case of one rail conductor the track rail is used as the return conductor.

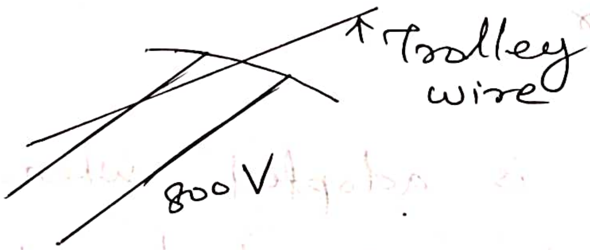
Overhead system

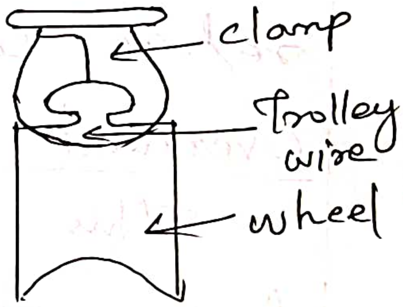
This system is adopted when the trains are to be supplied at high voltage 1500 V or above. The high power for trains may be supplied through conductors of relatively small cross section and collection of current required by a train can be done by a collector with siding contact.

Current collectors for traction overhead system

The current in the overhead system is collected with the help of sliding contact collector mounted on the roof of the vehicle. The main requirement of a current collector is that it should leave the contact of overhead equipment. Three types of current collectors are commonly used. They are Trolley collector, Bow collector and the Pantograph collector.

Trolley Collector

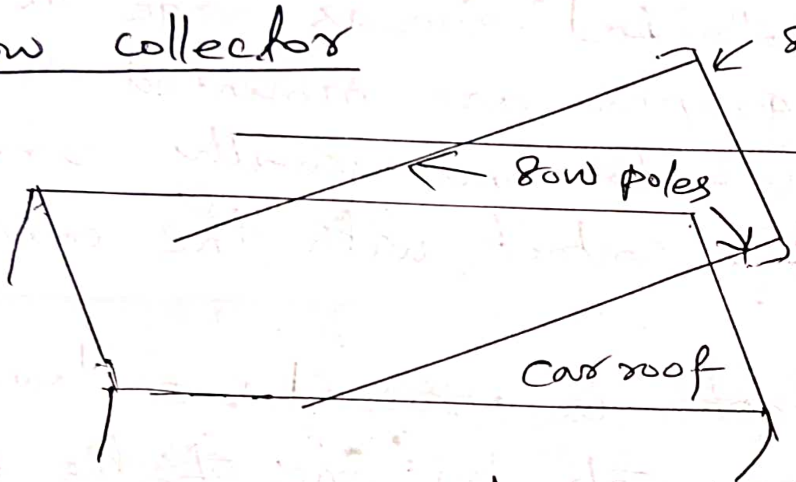




The trolley collector is employed with tramways and trolley buses. This consists of a grooved ~~gun~~ metal wheel or grooved slider shoe with carbon insert carried at the end of a long pole.

The other end of this pole is hinged to a swiveling base fixed to the roof of the vehicle. The necessary upward pressure for the pole and current collector is achieved by means of springs. As two trolley wires are required for a trolley bus, a seperate trolley collector is provided for each wire.

Bow collector



The bow collector consists of light metal strip or bow 0.6 or 0.9 m wide pressing against the trolley wire and attached to a frame work mounted on the roof of vehicle. The main advantage of bow collector is that it can be used for higher speeds and it is not suitable for trolley buses. Collection strip is made of soft material such as copper, aluminium or carbon so that it should wear instead of trolley wire as it is easy to replace worn out collection strip than trolley wire.

Pantograph collector

The Pantograph is employed in railways for collection of current where the operating speed is as high as 100 or 130 Kmph and current to be collected are as large as 2000 or 3000A. Pantographs are mounted on the roof of the vehicles and usually carry a sliding shoe for contact with the overhead trolley wire.

The pantograph is raised or lowered from the driver cab by one of the following methods.

a) air raised, gravity lowered
b) air raised, Spring lowered
c) spring raised, air lowered

The pantographs should maintain continuous contact with the overhead wire at resonably contact pressure at any height. If there is a serious trouble on the overhead system, the pantograph must be sufficiently pliable so that it will be damaged rather than pulling down the overhead structure.

2). Define specific energy consumption and discuss the factors which affect the specific energy consumption.

The total energy input to all the traction motors in a train is known as the energy consumption of the train. The specific energy consumption is the energy consumption in watt-hr, per tonne-km

$$\text{Specific energy consumption} = \frac{\text{Energy output in watt-hours}}{\text{Weight of train in tonnes} \times \text{Distance of run in km.}}$$

Factors which affect the specific energy consumption.

i). Distance between stops.

Greater the distance between stops, less will be the specific energy consumption are:

Main line service 18 to 31 watt-hr. per tonne km. Suburban service 50 to 75 watt-hr per tonne-km.

ii) Acceleration and retardation

Higher values of acceleration and retardation giving an increase in specific energy consumption

iii) Gradient:

Steep gradients will involve more energy consumption even though regenerative braking is employed

iv) Train resistance

This depends upon the nature of route, speed of the train and shape of the front and rear portions of the train. If the train resistance is greater, the specific energy consumption is more.

v). Train equipment

More efficient train equipment will reduce the specific energy consumption.

vi) The maximum speed.

vii) Weight of the train.

Two marks

1). Define Electrical drive

A drive is a combination of various systems combined together for the purpose of motion or movement control. The drive which employs electric motors for motion control are known as Electrical Drives.

2). What are the advantages of electric drives?

- Drives have flexible control characteristics.
- Drives can be provided with automatic fault detection systems
- They are available in wide range of torque, speed and power.
- Electric braking gives smooth deceleration and increases life of the equipment
- Starting and braking is simple and easy to operate.

3). Mention the parts of electrical drives.

i) Electrical motors and load ii) power modulator iii) Sources iv) Control unit v) Sensing unit.

4). Mention the application of electrical drives.

i). Paper mills ii) Electric traction iii) cement mills iv) steel mills.

5). What is meant by Electric traction?

The movement (locomotion) in which the driving force is obtained from electric motors is called the Electric traction system. Electric trains, trolley busses and electric vehicles are the examples of electric traction system.

6). What are the advantages of Electric Traction

i) High starting torque ii) Less maintenance cost iii) free from smoke and flue gasses iv) Rapid acceleration and braking v) Less vibration vi) It has great passenger carrying capacity.

7). What are the disadvantages of Electric traction.

i). High capital cost ii) Problem of supply failure iii) Additional equipment is required for achieving electric braking and control iv). The electrically operated vehicles have to move on guided track only.

③

8). What are the requirements of electric traction (or) ideal traction system?

i). The starting tractive effort should be high so as to have rapid acceleration ii). The wear on the track should be minimum iii) Speed control should be easy iv) Pollution free v) low initial and maintenance cost vi). Braking energy should be regenerated and returned to the supply.

9). What are the factors considered for the selection of electrical drive?

i). Nature of electric supply (or) source ii) Nature of the drive iii) Nature of load iv) Steady state and transient characteristics v) size and rating of motors vi) Capital and running cost.

10). What is meant by regenerative braking?

Regenerative braking occurs when the motor speed exceeds the synchronous speed. During traction movement in hilly areas downward direction, regenerative braking is applied. In this case induction motor runs as induction generator. During regenerative braking converting mechanical power into electrical power and excess electrical power is delivered back to electrical supply.

11). What is meant by plugging or reverse current braking?

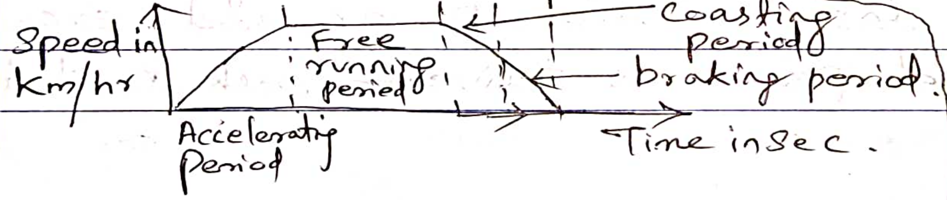
In this braking, connections of any two phases of stator ~~w.r.t to~~ with respect to supply terminals are interchanged. Motor develops a torque in opposite direction to the movement of the rotor. Motor will accelerate in opposite direction. The system speed decelerates and it comes to rest if disconnect the supply.

12). What is meant by dynamic (or) Rheostatic braking?

In this braking, the supply to the motor is disconnected during the braking period and external resistance is connected across it. All the kinetic energy of the moving parts are converted into electrical energy. This energy is dissipated as heat in the external resistance.

13) What is speed-time curve?

The curve drawn between speed in Km/hr along Y-axis and time in seconds along X-axis is called Speed-time curve. The Speed-time curve gives the complete information about the motion of the train.



14). What are the different types of speed used in traction?

(i) Crest speed

The maximum speed attained by the train during run.

ii) Average Speed

The mean of speeds from start to stop ie the distance between two stops divided by the actual time of run is known as average speed.

$$\text{Average speed} = \frac{\text{Distance between stops in km}}{\text{Actual time of run in hours}}$$

iii) Schedule Speed

The ratio of distance covered between two stops and total time of run including time of stop is known as schedule speed.

$$\text{Schedule speed} = \frac{\text{Distance between stops in km}}{\text{Actual time of run in hours} + \text{stop time in hours}}$$

15). What are the factors affecting Schedule speed?

i) Acceleration & Braking retardation
ii) Maximum or crest speed
iii) Stopping time or duration of stop

16). What ~~are~~ the need for Speed-time curve?

The movement of the train and their energy consumption can be studied from the speed-time curve. It shows the speed at different time instants after start of run.

~~16~~ What is tractive effort?

17) The effective force necessary to propel the train at the wheels of the locomotive to which the motor is geared is called the tractive effort. It is measured in Newtons and is tangential to the driving wheels.

UNIT - II.

Illumination

Introduction - definitions and meaning of terms used in illumination engineering - classification of light sources - incandescent lamps, sodium vapour lamps, Mercury vapour lamps, fluorescent lamps - design of illumination systems - indoor lighting schemes - factory lighting halls - outdoor lighting schemes - flood lighting - street lighting - energy saving lamps, LED

Introduction

Light is the prime factor in the human life. Where there is no natural light, use of artificial light is made. Artificial lighting produced electrically, on account of its clearliness, ease of control, reliability, steady output, as well as its low cost, it is very important part of our day to day life.

Aim of artificial lighting is to supplement the day light or even to replace it completely. Today human beings spend most of their time in buildings where artificial lighting plays an important role.

Good lighting, apart from having aesthetic and decorative aspects, reduces accidents, increases the production in the factories and improves the general health of the community due to reduction of eye strain.

Definition and meaning of terms used in illumination Engineering

1). Light

It is defined as energy from a hot body which produces the visual sensation upon the human eye. It is usually denoted by Q and expressed in lumen-hours.

2). Illumination

When the light falls upon any surface, the phenomenon is called the illumination. It is defined as the number of lumens, falling on the surface per unit area. It is denoted by the symbol E and is measured in lumens per square metre or lux.

3). Luminous flux (F)

It is defined as the total quantity of light energy emitted per second from a luminous body. It is represented by symbol F and is measured in lumens.

4). Luminous Intensity

The amount of light output falling on unit square metre of surface is called as Luminous Intensity. It's unit is lux.

5). Lux or Metre candle

It is the unit of illumination and is defined as the luminous flux falling per square metre on the surface which is every where perpendicular to the rays of light from a source of one candle power and one metre away from it.

6). Lumen

The lumen is the unit of luminous flux and is defined as the amount of luminous flux given out in a space represented by one unit of solid angle by a source having an intensity of one candle power in all directions.

Lumens = Candle Power (CP) x Solid angle (w)

7). Candle power

It is defined as the number of lumens given out by the source in a unit solid angle in a given direction. It is denoted by CP

8). Candela

It is the unit of luminous intensity. It is defined as 1/60 th of the luminous intensity per cm^2 of a black body radiator at the temperature of solidification of Platinum (2043K)

9). MHCP (Mean Horizontal Candle Power)

The mean of candle power in all directions in the horizontal plane containing the source of light is termed as Mean Horizontal Candle power.

10). MSCP (Mean Spherical Candle Power)

The mean of candle power in all directions and in all planes from the source of light is termed as Mean Spherical Candle power.

11). MHSCP (Mean Horizontal Spherical Candle Power)

The mean of candle power in all directions above or below the horizontal plane passing through the source of light.

12). Reduction factor

Reduction factor of a source of light is the ratio of its mean spherical candle power to its mean horizontal candle power.

$$\text{Reduction Factor} = \frac{MSCP}{MHCP}$$

13). Lamp efficiency

It is defined as the ratio of the ~~luminous~~ luminous flux to the power input. It is expressed in lemens per watt.

14). Luminance or brightness

It is defined as the luminous intensity per unit projected area of either a surface source of light or reflecting surface and is denoted by L.

15). Glare

It is defined as the brightness within the field of vision of such a character as to cause annoyance, discomfort, interferrence with vision ~~of~~ or eye-fatigue.

16). Space-height ratio
It is defined as the ratio of horizontal distance between adjacent lamps and height of their mountings.

$$\text{Space-height ratio} = \frac{\text{Horizontal distance between two adjacent lamps}}{\text{Mounting height of lamps above working plane.}}$$

17). Utilisation factor or coefficient of utilisation
It is defined as the ratio of total lumens reaching the working plane to total lumens given out by the lamp.

$$\text{Utilisation factor} = \frac{\text{Total lumens reaching the working plane}}{\text{Total lumens given out by the lamp}}$$

18). Maintenance factor
The ratio of illumination under normal working conditions to the illumination when the things are perfectly clear is known as maintenance factor.

19). Depreciation factor
It is defined as the ratio of initial metre-candles to the ultimate maintained metre-candles on the working plane. Its value is more than unity. This is the inverse of maintenance factor.

20). Waste light factor
There is always a certain amount of waste of light on account of overlapping and falling of light outside the edges of the surface.

The effect is taken into account by multiplying the theoritical value of lumens required by 1.2 for rectangular areas and 1.5 for irregullar areas and objects such as statues, monuments etc

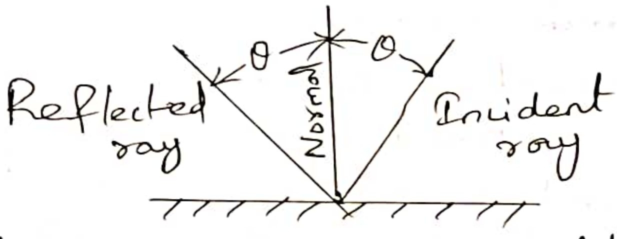
21). Absorption factor

In the places where atmosphere is full of smoke fumes, such as in foundaries, there is a possibility of absorption of light. The ratio of total lumens available after absorption to the total lumens emitted by the source of light is called the absorption factor.

22). Beam factor

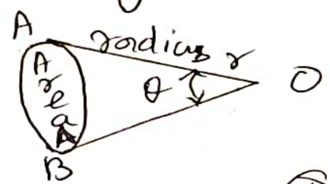
The ratio of lumens in the beam of a projector to the lumens given out by lamps is called the beam factor.

23). Reflection factor



The ratio of reflected light to the incident light is called the reflection factor. It is always less than unity.

24). Solid angle



Solid angle is the angle generated by the surface passing through the point in space and the periphery of the area. Solid angle is denoted by 'ω'

$$\omega = \frac{\text{Area}}{(\text{Radius})^2} = \frac{A}{r^2}.$$

25). <u>Plane angle</u>

Plane angle is subtended at a point in a plane by two converging straight lines and its magnitude is given by

$$\theta = \frac{\text{Arc}}{\text{Radius}} \text{ radians.}$$

The largest angle subtended at a point is 2π radians.

<u>Relationship between plane angle and solid angle</u>

$$\omega = 2\pi \left[1 - \cos\left(\alpha/2\right)\right]$$

<u>Laws of Illumination</u>

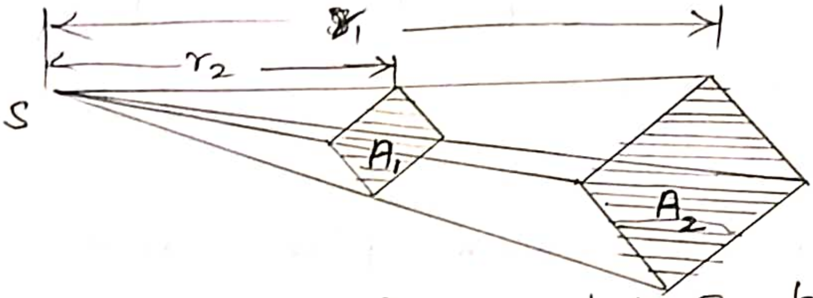
There are laws illumination

1). Law of Inverse squares
2). Lambert's Cosine law

<u>Law of Inverse Squares</u>

Illumination at a point is inversly proportional to square of its distance from the point source and directly proportional to the luminous intensity (CP) of the source of light in that direction

If a source of light, which emits light equally in all directions, be placed at the centre of a hollow sphere, the light will fall uniformly on the inner surface of the sphere. If the sphere be replaced by one of the larger radius, the same total amount of light is spread over a larger area proportional to the square of the radius.



As shown in figure let I be the luminous intensity of a point source expressed as lumens (steradion). Let ω be the solid angle considered.

Total light flux in ω steradians = Iω

Area of surface at radius r_1, $A_1 = r_1^2 \omega$

Area of surface at radius r_2, $A_2 = r_2^2 \omega$

Illumination at surface of radius $r_1 = E_1 = \frac{I\omega}{r_1^2 \omega} = \frac{I}{r_1^2}$

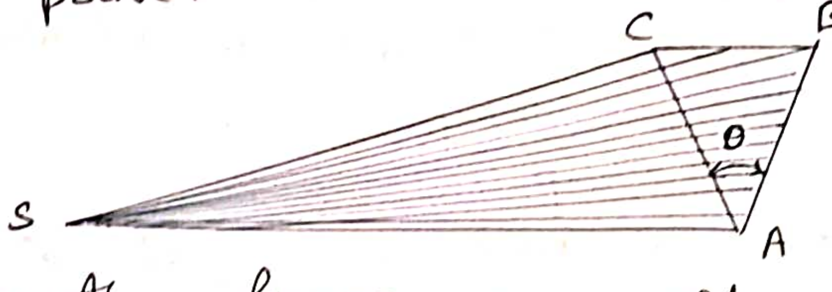
Illumination at surface of radius $r_2 = E_2 = \frac{I\omega}{r_2^2 \omega} = \frac{I}{r_2^2}$

$$\therefore \frac{E_1}{E_2} = \frac{r_2^2}{r_1^2}$$

Hence from the above equation, the illumination of surface is inversely proportional to the square of the distance between the surface and the light source provided that the distance between the surface.

Lambert's Cosine law

The illumination at a point on a surface is proportional to cosine of the angle which ray makes with the normal to the surface at that point.



Consider the figure, very often the illuminated surface is not normal to the direction of light as AC in figure, but is inclined as AB. The area over which the light is spread is then increased in the ratio.

$$\frac{AB}{AC} = \frac{1}{\cos\theta}$$

And the illumination decreases in the ratio $\frac{\cos\theta}{1}$

The expression for the illumination then becomes,

$$E = \frac{I\cos\theta}{r^2}$$

According to this law, the illumination at any point on a surface is proportional to the cosine of the angle between the normal at that point and the direction of luminnous flux.

Classification of lamps

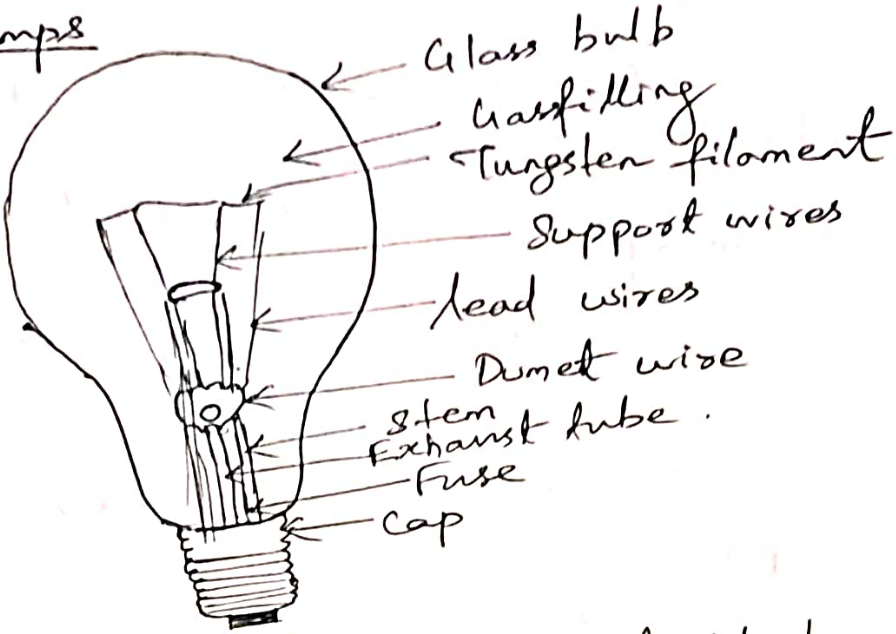
1). Arc lamps
   a). Carbon Arc lamp
   b). Flame Arc lamp
   c) Magnetic-Arc lamp
2). Incandescent lamps or Filament lamps
   d) Halogen lamp
   e). Cold lamp
3). Gaseous discharge lamps/High intensity Discharge (HID) lamps
   f) Sodium-vapour lamp
   g). Mercury-vapour lamp
   h) Mercury Iodide lamp
   i) Neon lamp
   j) Neon tube
   k) Flourescent tube

Incandescent lamp

When an electric current is passed through a fine metallic wire, heat is produced and the temperature of the wire increases. At low temperature the wire radiates heat energy, as the temperature increases due to heating it radiates heat as well as light energy.

The incandescent lamp consists of a glass globe completely evacuated and a fine wire, known as fillament within it. The glass globe is evacutated to prevent the oxidation and convection currents of the filament and also to prevent the temperature being lowered by radiation.

Gas filled lamps

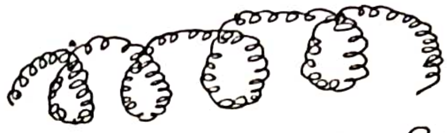


Incandescent lamps produce light by means of a filament heated to incandescence by the flow of electric current through it. A material tungsten in the case of filament lamps heated until it gives off visible light. The lamp includes the filament, the bulb, the fill gas and the cap.

When the body is heated, it emits radiant energy in the light. The amount of light emitted is proportional to the absolute temperature. The filament lamp consists of a filament covered in a glass cover filled with inert gas. The tungsten material is almost commonly used in filament lamp. The filament is made of coiled coil/ tightly wound helical structure.

To avoid the filament from oxidation and avoid heat conduction, filament is covered with inert gas. The commonly used inert gas is mixture of 85% Argon & 15% Nitrogen. The typical life of filament lamp is 1000 burning hours. The luminous efficiency of filament lamp is 8 to 14 lumens output per watt of power consumption.

Coiled filament

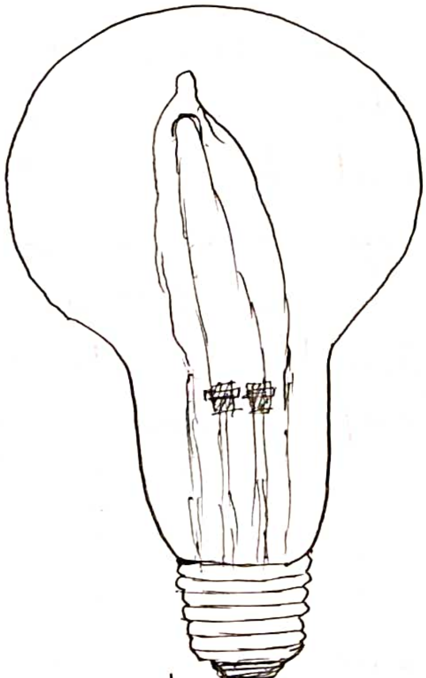


Coiled coil filament

The light output depends upon the cubic power of the working voltage. 10% reduction in supply voltage from the rated voltage will reduce the light output by 27%.

The filament lamp is the most inefficient form of lighting. It produces more heat than light. Filament lamp is used for heating purpose in poultry farm and equipment drying applications.

<u>Halogen lamp</u>



Halogen bulb

A tungsten Hologen lamp is a type of incandescent lamp with a tungstent filament contained within an inert gas and a small amount of halogen such as iodine or bromine. The filament of the small lamp is surrounded with halogen gas. As the tungsten burns off, the halogen reacts with the tungsten, creating a bright light.

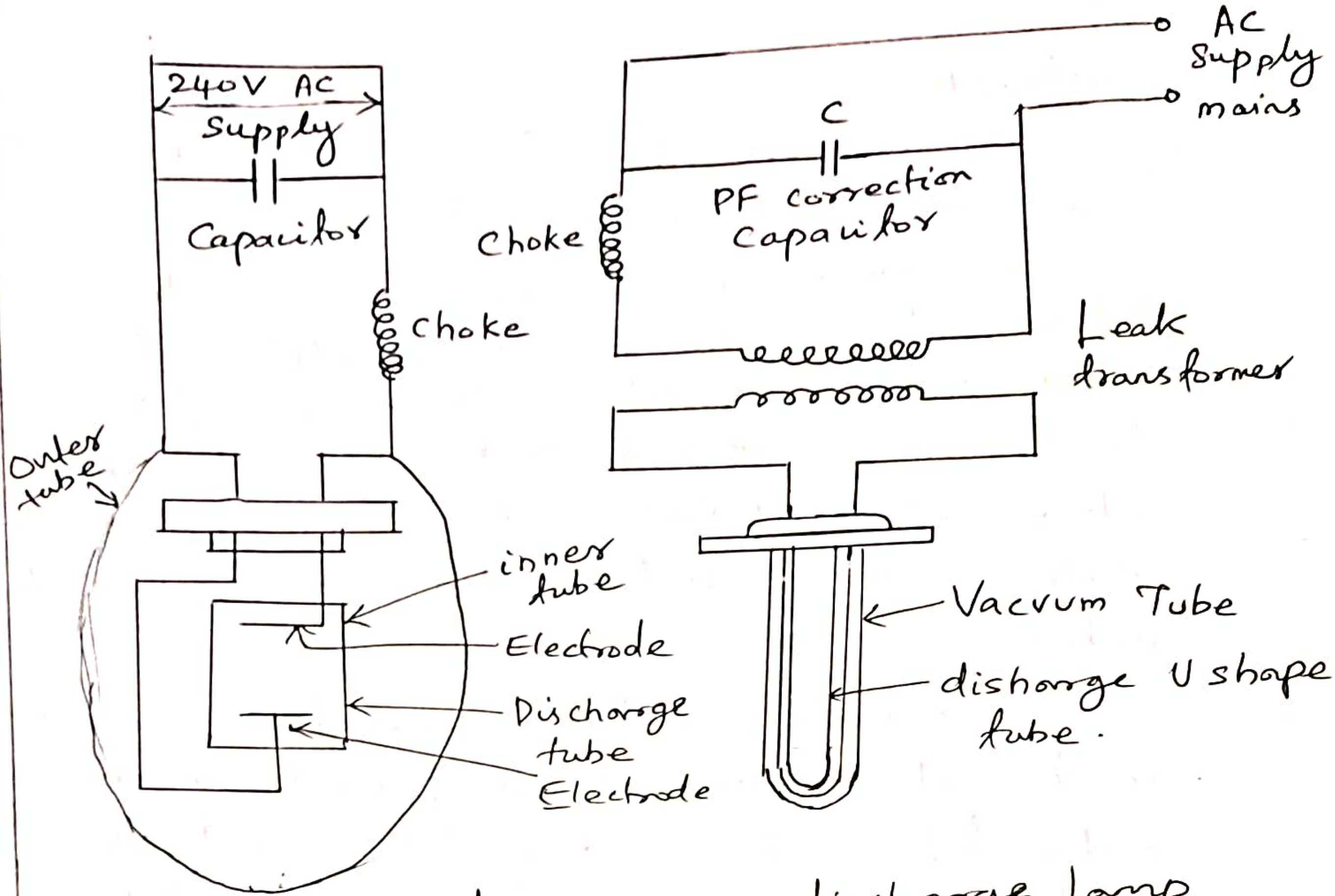
Tungsten-Halogen lamp is slightly different shape and thicker heavier glass bulb. ~~Ans~~ In ~~incandescent lamp~~ ordinary incandescent lamp the filament evoparates over time and bulb wall blackens slowly as tungsten is deposited on it.

The combination of the halogen gas and the tungsten filament producos a chemical reaction known as a halogen cycle with increases the life time of the filament and prevents darkening of the bulb by redepositing tungsten from the inside of the bulb back onto the filament. lamp life ranges from 2000 hours to 20000 hours. prevents darkening of the bulb by whiter and brighter throughout its life.

This newer type of incandescent lighting achieves better energy efficiency than standard bulbs. It has gas filling and inner coating that reflect heat. These lamps are more expensive than standard incandescent lamps.

Sodium Vapour Discharge lamp

- Sodium discharge lamp consists of a bulb containing a small amount of metallic sodium, neon gas and two sets of electrodes connected ~~to~~ to a pin type base.
- The presence of neon gas is to start the discharge to develop enough heat to vaporize the Sodium. The 'U' shape arrangement is used for discharge.
- Sodium vapour lamp is suitable only for A.C supply and therefore, requires choke control. This requirement is met by operating the lamp from a stray field, step-up, tapped auto transformer with an open-circuit secondary voltage ~~upto~~ of 470 to 480 volts. The uncorrected power factor is very low, about 0.3 and a capacitor must be used to improve the powerfactor to about 0.8.
- When the lamp is not in operation, the sodium is usually in the form of solid deposited on the side walls of the tube, therefore, at first when it is connected across the supply mains the discharge takes place in the neon gas and gives red-orange glow



Sodium vapour discharge lamp

- The metallic sodium gradually vaporizes and then ionizes, thereby producing the characteristics mono-chromatic yellow light, which makes objects appears as grey. The lamp will come up to its rated light output in approximately 15 minutes
- The efficiency is 40-50 lumens/watt
- Major applications are for highway and general outdoor lighting, street lighting, parks, rail yards. Such lamps are with ratings 40, 60, 85 and 140 watts. The average life is about 3000 hours.

Construction :
It consists of two glass tube, outer glass tube and inner glass tube.
The inner glass tube contains two electrodes. Sodium along with small quantity of neon or argon gas is filled in the inner tube to make discharge self-starting. Sodium vapour is chemically active. The glass of the tube is made up of suitable material to resist this action.
To maintain the correct temperature in the discharge, it is placed in an evacuated outer tube. The outer tube reduces the heat loss. The transformer includes in the circuit heats the cathode while choke stabilizes the discharge.

Working:
When the lamp is not in operation. The sodium is usually in the form of solid deposited on the side walls of the tube. When the lamp is switched ON, the discharge is first established through the neon or argon gas. This gives out radish colour. After some time heat is developed due to this discharge that is vaporizes sodium vapour. In this way the lamp ~~star~~ starts its normal operation giving yellow colour.

Capacitor C is connected to have a better power factor. The operating temperature of this lamp is about 300°C. Lamp is not affected by voltage variations. Light output reduces by 15% due to ageing. The metallic sodium gradually vaporizes and then ionizes. Thereby, producing the characteristics mono-chromatic yellow light, which makes objects appears as grey. The lamp must be operated horizontally or nearly so, to take the sodium well spread out along the tube. Some operated vertically as designed.

Mercury Vapour lamp

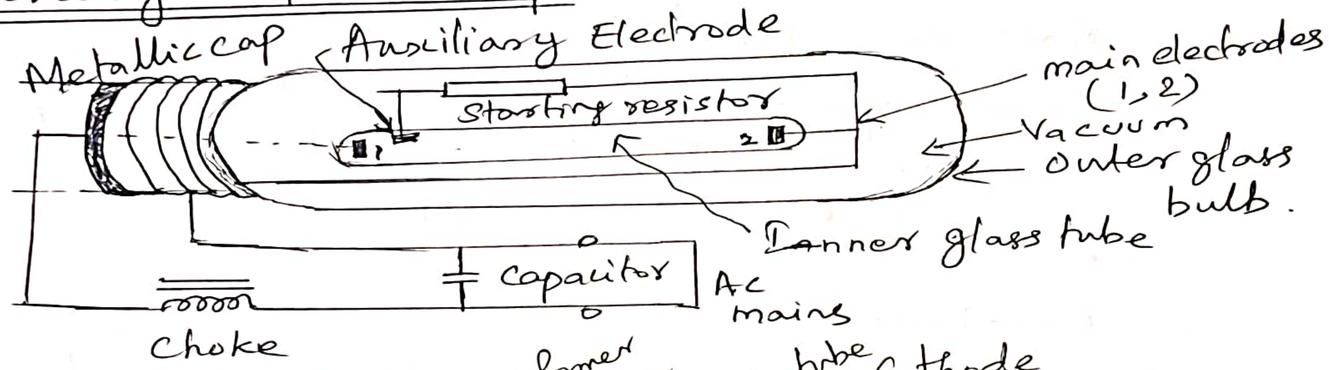


Fig (a)

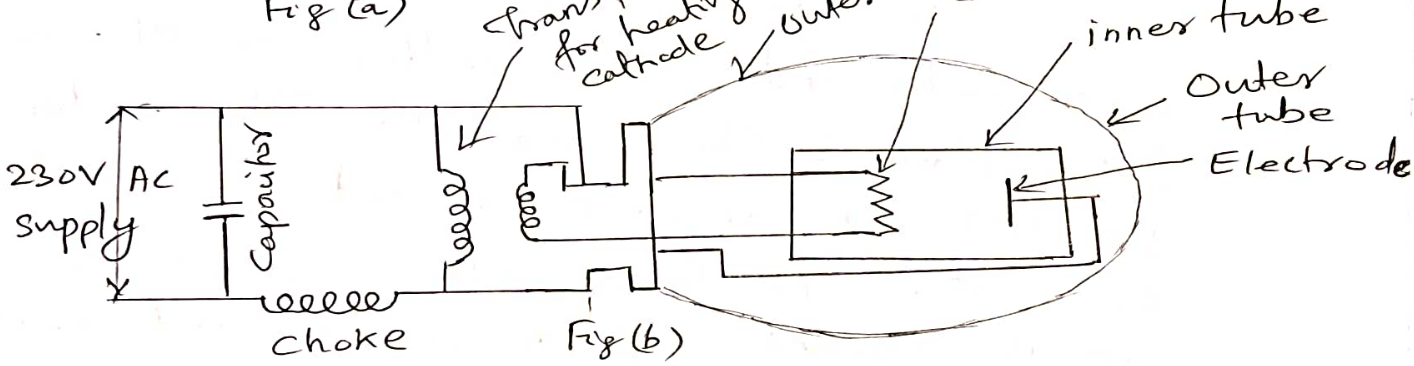


Fig (b)

Mercury vapour lamp a) Arrangement b). Components

High pressure vapour lamp is an electric discharge lamp, in which light is produced by gaseous conduction. The two main electrodes are placed inside a glass tube filled with Argon gas and small quantity of mercury.

An auxiliary electrode is also placed close the electrode connected to the ballast. The purpose of the auxiliary electrode is to start the initial conduction.

The glass tube is covered with another glass cover. The electrodes are madeup of Tungsten coils, coated with barium oxide. The arc is confined to a small inner hard glass or quartz tube, which surrounds the larger glass bulb. The space between the inner and outer tube is completely ~~evacuat~~ evacuated to prevent heat-losses.

Construction

The lamp consists of two bulbs, inner bulb and outer bulb. The electric discharge takes place in the inner bulb. The outer bulb protects the inner bulb and reduces the loss of heat. The inner bulb consists of a small amount of mercury and argon gas.

Two main electrodes and auxiliary electrode are provided in the inner bulb. Choke and Capacitor forms the control circuits of the lamp. The main electrode 2 is connected to auxiliary electrode through a high resistance.

Working:

When the supply is switched ON, the initial discharge is established between main electrodes 1 and 2 through the argon gas then between electrodes 2 and auxiliary electrode. The heat produced due to this discharge is sufficient to vaporize mercury and the discharge through the mercury vapour takes place. In this normal operation of the lamp, it emits or radiates its characteristic light. The auxiliary electrode is also called as starting electrode.

The choke serves to limit the current drawn by the electrodes to a safe limit. The capacitor C improves power factor of the lamp. These lamps are widely used for street lighting where a high illumination necessary, where the colour of light is not important.

Flourescent lamps

The light produced by a flourescent tube is caused by an electric current conducted through mercury and inert gases. Flourescent lighting is used mainly indoors both for ambient and task lighting and is about 3 to 4 times as efficient as incandescent lighting.

Flourescent light need ballasts (devices that control the electricity) for starting and circuit protection. In flourescent tubes, a very small amount of mercury mixes with inert gases to conduct the electrical current. This allows the phospher coating on the glass to emit light.

Basic components of a Fluorescent lamp

Bulb: Usually a straight glass tube can be circular, U shaped or curved

Phosphor: Coating inside the bulb that transforms ultraviolet radiation into visible light.

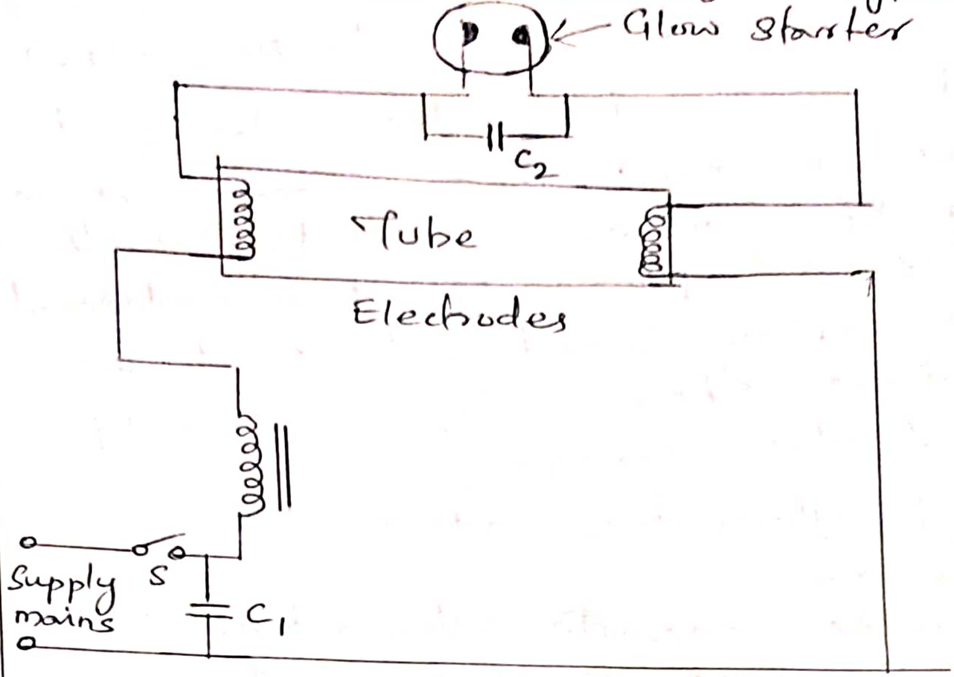
Base: Used to connect the lamp to the circuit and support it in the fixture.

Cathode: located at each end of the lamp. cathodes are coated with a material that emits electrons and usually are made off coiled coil or single coil tungsten wire.

Gas: argon or a mixture of inert gas at low pressure - krypton sometimes used.

Mercury: a minute quantity of liquid mercury is placed in the bulb to furnished mercury vapour.

Flourescent tube with glow type starter



It consists of two bimetallic electrodes enclosed in a glass bulb filled with a mixure of helium and hydrogen. Normally the contacts are open.

When the supply is switched on, the potential across bimetallic electrodes causes a small glow discharge at a small current not enough to heat up the tube or filament.

By making contact or bimetallic strips switch, large current flows through the electrodes, due to that temperature raises towards ionization. After few seconds the bimetallic strips cool down and the contacts open.

Compact Fluorescent lamp (CFL)

Compact fluorescent lamps (CFLs) are the most significant lighting advance developed for homes in recent years. They combine the efficiency of fluorescent lighting with the convenience and popularity of incandescent fixtures. CFLs can replace incandescents that are roughly 3 to 4 times their wattage, saving upto 75% of initial lighting energy.

Design of illumination system

Objectives are

- To provide adequate illumination
- To provide light distribution all over the area uniformly
- To provide light of uniform colour
- To avoid glare and hard shadows.

Design methodology

1). Calculate area to be illuminated

2). Describe the level of illumination

3). Total illumination = Area illumination level

4). Select utilization factor and depreciation factor.

5). Divide total illumination by utilization factor and depreciation factor.

6). If depreciation factor is greater than 1, then it find gross lumen, it is multiplied with total lumen instead of division.

7). Select lamp and luminaries
8). Determine number of lamps
9). Decide arrangements of lamps for uniform distribution considering space to height ratio.

Lighting scheme designing factors (or) requirements of good lighting

1) Illumination level

This is the important factor, based on the illumination level, the visibility of objects and its acquiring of brightness is decided

2) Uniformity of illumination

If there is uniformity pupil or iris of the eye has to adjust more frequently and thus fatigue is caused to the eye.

3) Colours of light

The body colour appearance depends upon the colour of the incident light. The composition of the light should be such that the colour appears natural.

4). Shadows

In lighting installation, formation of long and hard shadows is considered to be a fault as this involves rapid fatigue of eyes.

5). Glare

Light enters the eye directly from the source of light produces glare.

Glare which is caused by the source of light is called direct glare. Reflected glare is glare which comes to the eye as the reflection of the light source in some polished surface.

It can be reduced by,

i). Increasing the height of the lamp

ii) Using reflectors which cut off the light at 20° to horizontal.

b). <u>Mounting height</u>

In case of direct lighting, in rooms of large floor area, the luminaries should be mounted as close to the ceiling as possible

Design of indoor lighting

While designing indoor lighting installation, following factors have to be taken into consideration.

a). <u>Illumination level</u>

This is the most important factor which affects the total wattage of the lamps in an installation.

b). <u>Quality of light</u>

By quality of light, absence of glare, absence of contrast and absence of deep shadows. Presence of Polished and glossy material will cause indirect glare unless diffused light is used c). Physical conditions of the premises

In indoor lighting, the light reaching the object not only from the source, reflections from the ceiling and walls also. Colour and decoration of the same deciding very much portion of the reflected or diffused light.

d). Colour of light

Use highly efficient discharge lamps which are not free from colour distortion effect

e) Financial aspects

Installation cost depends upon the type of lamp and fittings used.

Total lumen method of calculation

In case of indoor lighting installation, illumination on working plane is not only due to the light flux directly received from the light source but there is contribution of the same from walls and ceiling. Hence illumination on working plane is calculated by taking into account that portion of flux which actually reaches it.

Coefficient of utilisation is used to know the magnitude of useful flux. It depends upon following factors

1). Polar curve of the lamp fitting : Coef. of utilisation is more for direct type of fittings and becomes less and less as fittings become more and more indirect.

2). Geometric proportion of space : If the mounting height becomes more and more the portion of the light flux reaching the working plane directly decreases and therefore, coefficient of utilisation also decreases.

3). Reflection factors of the decorations and furnishings

Coef. of utilisation will be more for light colours and less for dark colours.

Design of outdoor lighting

Design of outdoor lighting, there are two schemes

1). Flood lighting 2). Street lighting.

Street lighting

The main purpose of street lighting are, 1). To promote safety and convenience on the streets at night through adequate visibility.

2). To increase the attractiveness of the street.

3). To increase the community value of a street.

The level of illumination has to be low for economic reasons and the colour of the objects is not important. There should be no glare as far as possible.

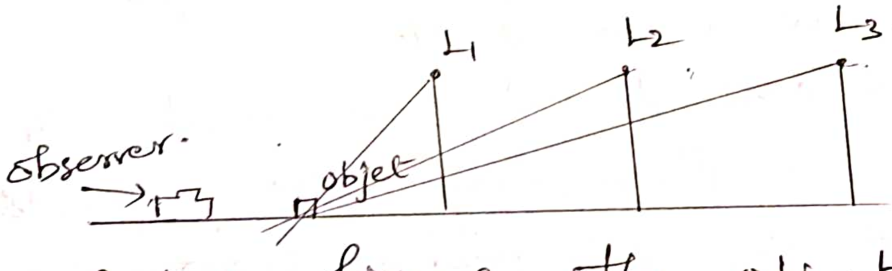
The design of street light installations are based on two principles

a). <u>The diffusion principle</u>

The lamps are fitted with suitable reflectors which spread the light as uniformly as possible over the road surface. The road surface appears bright to the observer. The reflectors are so shaped that the lamp filament is not visible except from underneath it. It avoids glare.

b). <u>The specular reflection principle</u>

In this method, light falls on an object at a very large angle of incidence and is therefore reflected at a correspondingly large angle.



By referring figure, the object will appear bright against the bright road surface on account of the light from lamps L_2 and L_3 rather than L_1. Since L_2 and L_3 throw light on the road surface at a large angle of incidence. The reflector should be designed that it throws light on the road surface at a very large angle of incidence.

Flood lighting

Flood lighting means flooding of large surface areas with light from powerful projectors. A special reflector and housing is employed in flood lighting in order to concentrate the light emitted from the lamp into a relatively narrow beam, which is known as flood light projector. An importance application of illumination engineering is the flood lighting of large and open area. It is employed to serve the following purposes

1). Aesthetic flood-lighting

For enhancing beauty of building at night such as public places, ancient buildings and monuments, religious buildings on important festive occasions etc.

2). Industrial and commercial flood lighting

For illuminating railway yards, sports stadiums, car parks, construction sites, quarries etc.

3). Advertising

For illuminating advertisement boards and show cases.

- For small buildings, uniform flood lighting is used. Flood lights can be placed on other buildings nearby or on suitable posts at distances of not more than about 60 metres. Light should fall nearly perpendicular to the building.
- Large or taller buildings are illuminated non-uniformly. Flood lights should be so located that contours and features of the building are well defined. If any shadows are cast, they should enhance the beauty of the building or monument.
- For flood lighting ground surfaces, the requirement is placed at sufficient height on poles or on the roofs of buildings nearby. The main consideration is to reduce glare.

<u>Flood lighting calculations</u>

The three steps of lighting calculations are

1). <u>Illumination level required</u>

The illumination level in $lumens/m^2$ depends upon the type of building, the type of flood lighting, the amount of light etc.

2). <u>Type of projector</u>

- Beam size
- Light output

Based on the above two considerations, choice of projector is made. The beam size determines the area covered by the beam and the latter the illumination provided.

3). Number of projectors

$$N = \frac{A \times E \times \text{Depreciation factor} \times \text{Waste light factor}}{\text{Utilisation factor} \times \text{Wastages of lamp} \times \text{Luminous efficiency of lamp}}$$

where N – number of projectors
A – area of surface to be illuminated in m^2
E – Illumination level required in lumens/m^2.

Factory lighting

- An adequate amount of light in an industrial establishment increases the productivity of labour, improves the quality of the work and product, reduces the number of work stoppages and also helps to reduce accidents
- The object of any lighting scheme should be that the human eye should be able to do its work properly and without causing fatigue or damage to itself.

Good lighting in the factory should fulfill the following

- There should be enough illumination for the eye to see details clearly without strain or fatigue
- The shape of objects should be clearly visible to the eye on account of proper brightness contrast
- There should be no glare or dazzling effect from the light sources.

- Safety lighting fittings must be provided so that they can be used in the event of failure of the main supply or in the event of an accident.
- Glare must be avoided as far as possible. This can be achieved by a general increase in illumination, by using diffusing shades.

In factory premises, good lighting is required for illuminating shop floor, storage spaces and parking sheds etc. In work shops, the bins containing tools should be illuminated to read the labels for identifying the contents quickly. Wherever process work is done, individual workers are provided additionally with seperate lighting. While designing the lighting scheme care should be taken to see that the average illumination matches with the natural broad day-light.

The requirements of most of the installations can be met by one of the following type of fittings

- standard reflectors
- Connecting reflectors
- Angle reflectors
- Diffusing fittings
- Enclosed diffusing fittings.

Energy Saving Lamps

Energy saving lamps are sources of artificial light that employ advanced technology to reduce the amount of electricity used to generate light, relative to traditional filament burning light bulbs.

Examples

1). Fluorescent lamps, ie regular and compact
2). Light Emitting Diode bulb.
3). Light Emitting Electrochemical cell
4). Magnetic induction lamps.

The following are the few examples of energy saving opportunities with efficient lighting.

Installation of Compact Fluorescent lamps (CFL's) in place of Incandescent lamps

Compact fluorescent lamps are generally considered best for replacement of lower wattage incandescent lamps. The averge lamp life is 10000 hours, which is 10 times longer than normal incandescent lamps. CFL's are highly suitable for places such as living rooms, Hotel lounges, Bars, Restaurants, Corridors etc

Installation of metal halide lamps in place of mercury/ Sodium vapour lamps

Metal halide lamps provide high colour rendering index when compared with mercury & Sodium vapour lamps. These lamps offer efficient white light. Hence metal Halide is the choice for colour critical applications where, higher illumination levels are required.

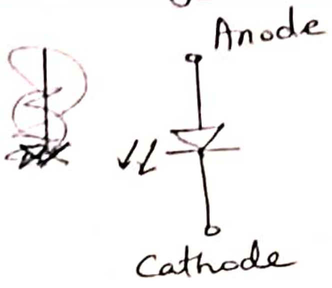
Installation of High pressure Sodium Vapour (HPSV) for application where colour rendering is not critical

High pressure Sodium vapour (HPSV) lamps offer more efficiency. But the colour rendering property of HPSV is very low. Hence it is recommended to install HPSV lamps for such street lighting, yard lighting etc.

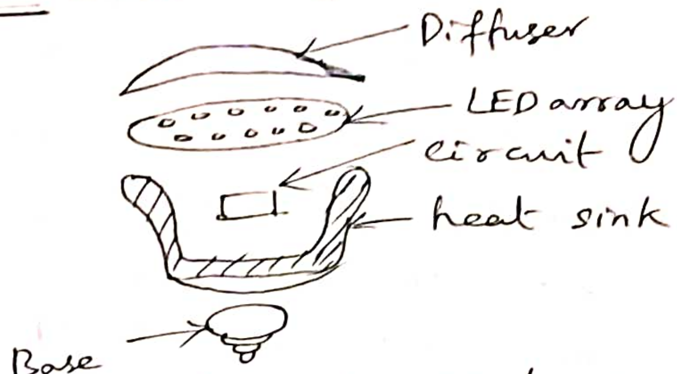
Installation of LED panel indicator in place of filament lamps

Panel indicator lamps are widely used in industries for monitoring, fault indication, signaling etc. LED lamps are lesser power consumption. and withstand high voltage fluctuation in the power supply. They have longer operating life (more than 1,00,000 hours)

Light Emitting Diode (LED lamps)



Symbol



Typical LED lamp

These are five main parts of a typical LED lamp

1). Diffuser

Individual LED's have lenses built into them at the top so they fire their light in one direction. Put 10-20 of them together and get quite a glaring beam like an oversized flash light. Diffusers are typically frosted plastic domes that spread the LED beams into a fluzzier, more even glow, sending equal light in all directions.

2). LED array

These are one or two dozen LEDs in a bulb.

3). Heat Sink

Although LEDs are energy efficient, they still generate some amount of heat. Because the lamp is a completely sealed unit, the generated heat damage the components inside. Heat sinks cool them down.

4). Circuit.

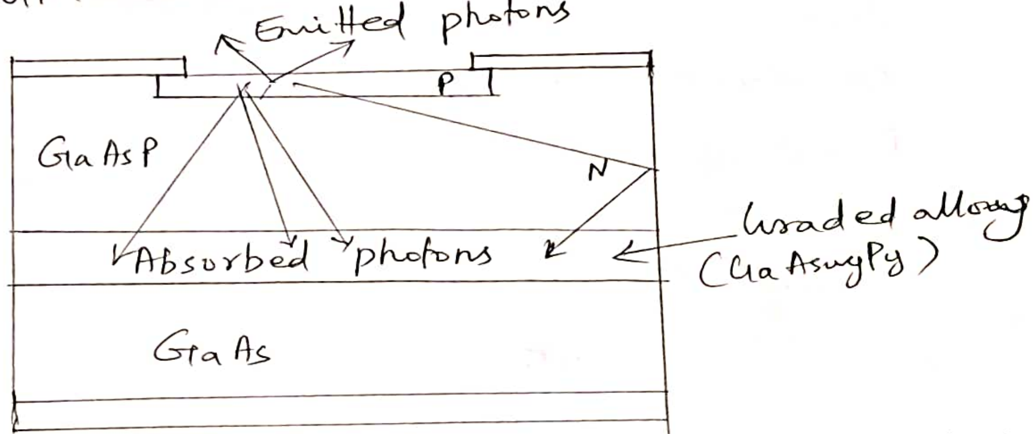
A transformer and a few other components convert high voltage domestic AC to DC power for the LED array.

5). Base

Usually either a screw in or bayonet fitting.

Principle of operation

LED's are P-N junction devices which emit light when forward biased. The P-N junction is formed using direct band gap materials such as gallium arsenide (GaAs), gallium antimonide (GaSb), indium arsenide (InAs), indium antimonide (InSb) etc.



Typical structure of LED with GaAs substrate.

The device structure consists of GaAsP grown on GaAs substrate. GaAsP grown on GaAs substrate may produce lattice mismatches. Hence, a graded alloy $GaAs_{1-y}P_y$ layer is grown epitaxially between the substrate and the active region to minimize the nonradiative centres at the interface that result from lattice mismatch. ~~For red LED~~

LEDs emit light when they are forward biased. Under forward biased condition, carriers acquire enough energy to overcome the potential barrier existing at the junction. When forward voltage is applied, minority carriers are injected across the junction and they recombine with majority carriers. These recombination's may be either radiative or nonradiative. Radiative recombination's emit light and nonradiative recombination's produce heat.

Problems

1). Calculate the total flux from the lamp having M.S.C.P of 35.

Solution

$$MSCP = \frac{\text{Total flux}}{4\pi}$$

$$\text{Total flux} = MSCP \times 4\pi$$

$$= 4\pi \times 35$$

$$= 440 \text{ lumens}.$$

2) A 250 volt lamp has a total flux of 3000 lumens and takes a current of 0.8 amp. Calculate (i) Lumens/watt ii) MSCP/watt.

Solution

Wattage of lamp $= 250 \times 0.8 = 200$ watts

Flux emitted $= 3000$ lumens

Lumens/watt $= \frac{\phi}{\omega} = \frac{3000}{200} = 15$

$$MSCP = \frac{\phi}{4\pi} = \frac{3000}{4\pi} = 238.7$$

3). A lamp of uniform intencity of 100 CP is enclosed inside glass globe. 25% of the light emitted by lamp is absorbed by the globe. Determine i) Brightness of globe 2). C.P of globe, dia of globe is 20 cm.

Solution

Dia of globe $= 20$ cm

Surface area of globe $= 4\pi r^2 = 4\pi \times (10)^2 = 400\pi$ cm^2

C.P of the lamp $= 100$

Total lumens emitted by the lamp $= 4\pi \times 100$

$= 400\pi$ lumens

light absorbed by the globe $= 25\%$.

$\therefore$ light emitted from the globe $= 400\pi(1-0.25)$

$= 400\pi \times 0.75$

$= 300\pi$.

$$\text{Brightness of globe} = \frac{\text{light emitted by globe}}{\text{Surface area of globe}}$$

$$= \frac{300\pi}{400\pi} = 0.75$$

$$\text{C.P of globe} = \frac{\text{Lumens emitted from globe}}{4\pi}$$

$$= \frac{300\pi}{4\pi} = 75 \text{ C.P.}$$

(4). The illumination of drawing office 30m X 10m is to have a value of 250 lux and is to be provided by a No of 300 W filament lamps. If the co efficient of utilisation is 0.4 and depreciation factor is 0.9 and luminous efficiency of each lamp is 14 lumens per watt, determine the number of lamps required.

Solution

Area of drawing office $= 30 \times 10 = 300 \text{ m}^2$

Illumination = 250 lux

Wattage of lamps = 300 watt.

U.F = 0.4

D.F = 0.9.

luminous efficience = 14 lumens/watt

Gross lumens output required from source

$$= \frac{E \times A}{U.F \times D.F} = \frac{300 \times 250}{0.4 \times 0.9}$$

$= 208333.33$ lumens

Flux emitted per lamp = Wattage × efficiency

$= 300 \times 14 = 4200$ lumens

$$\text{Total no of lamps required} = \frac{\text{Gross lumens}}{\text{lumens output of one lamp}}$$

$$= \frac{208333.33}{4200}$$

$= 49.6 = 50.$

Two marks

1) Define beam factor.
refer definitions

2) Define Utilization factor
refer definitions

3) State law of illumination
refer law of inverse square and Lambert's cosine law

4) Write the various factors for designing the lighting schemes
i) Illumination level ii) Uniformity of illumination iii) Colour of light
iv). shadows v). Glare vi) Mounting height

5) Define the terms lumens and Lux
Refer definitions

6). Define space-height ratio
It is defined as the ratio of horizontal distance between adjacent lamps and height of their mountings.

$$\text{Space-height ratio} = \frac{\text{Horizontal distance between two adjacent lamps}}{\text{Mounting height of lamps above working plane}}$$

7). What is stroboscopic effect of fluorescent tubes?

With A.C supply frequency of 50 cycles per second, discharge through the lamp becomes zero, 100 times in a second. Due to the persistence of vision, our eyes do not notice this. If this light falls on moving parts, they may appear to be either running slow or in the reverse direction or even may appear stationary. This effect is called stroboscopic effect.

8). What is meant by luminance?
refer definitions

9). Define luminous flux
refer definitions

10). What is meant by candle power?
refer definitions

11). Define MHCP and MSCP
refer definitions.

12). What are the advantages of Incandescent lamps?
i) less expensive
ii) Easier to dim with rheostats
iii) Warmer colour than fluorescent and tungsten-Halogen lamps
iv) light output is relatively high.

13). What are the disadvantages of incandescent lamps?
i). Energy inefficient
ii) Short lamp life time
iii) Warm source

14). What are the drawbacks of discharge lamps?
i). Time taken to attain full brightness
ii) High initial cost and poor power factor.
iii) light output fluctuates at twice the supply frequency.
iv) These lamps can be used only in particular position.

15). What are the advantages and disadvantages of sodium vapour lamp.
Advantages
i). Its efficiency is higher than that of the filament lamp ii) It has a long life.

Disadvantages

i) The bright yellow colour obtained is not suitable for indoor lighting. So it is not useful in houses

ii) For the necessary output, long tubes are required.

iii) For giving full output, some time is required. (about 10 minutes)

16). What are the advantages and disadvantages of mercury vapour lamp?

Advantages

i) Its efficiency is high and output is more

ii) It has a long life

Disadvantages

i) The initial time required for warming up is more about 5 minutes.

ii) Cooling is required for restarting while servicing. Cooling reduces the vapour pressure.

iii) Mercury which can be harmful to both humans and wild life.

measurement

uniform

UNIT – III

Heating and Welding

Introduction – advantages of electric heating – modes of heat transfer – methods of electric heating – resistance heating – arc furnaces – induction heating – dielectric heating – electric welding – resistance welding – arc welding – power supply for arc welding – radiation welding

Introduction

When Electric current passes through a medium (solid, liquid and gas) heat is produced. This basis is called Electric heating. It is extensively used for domestic as well as industrial applications.

Electric heating is a process in which electrical energy is converted to heat. An electric heater is an electrical device that converts electric current to heat. The heating element inside every electric heater is an electrical resistory and works on the principle of Joule heating. An electric current passing through a resistor will convert that electrical energy into heat energy. Common applications of electric heating are space heating, cooking, water heating and industrial processes.

In case of a solid material which has a resistance 'R' ohms and current flowing through it is 'I' amperes for 't' seconds the heat produced in the material will be

$$H = I^2RT \text{ Joules}$$

$$H = \frac{I^2RT}{4.2} \text{ calories.}$$

$$1 \text{ kcal} = 4186 \text{ Joules}$$

$$1 \text{ cal} = 4.186 \text{ Joules.}$$

Advantages of electric heating

1). Cleanliness

Since neither dust nor ash is produced in electric heating, it is a clean system of heating requiring minimum cost of cleaning

2) No pollution

Since no flue gases are produced in electric heating, no provision has to be made for their exist

3). Economical

Electric heating is economical because electric furnaces are cheaper in their initial cost as well as maintenance cost since they do not require big space for installation or for storage of coad and wood.

4). Ease of control

It is easy to control and regulate the temperature of an electric furnace with the help of manual or automatic devices.

5). Special heating requirement

Special heating requirements such as uniform heating of a material or heating one particular portion of the job without affecting its other parts.

6). Higher efficiency

Most of the heat produced is utilised for heating the material itself. Hence, electric heating has higher efficiency as compared to other types of heating

7). Better working conditions

Since electric heating produces no irritating noises and also the radiation losses are low, it results in low ambient temperature. Hence, working with electric furnaces is convenient and cool.

8). Heeating of bad conductors

Bad conductors of heat and electricity like wood, plastic and bakery items can be uniformly and suitably heated with dielectric heating process

9). Safety

Electric heating is quite safe. because it responds quickly to the controlled signals.

10) Lower attention and Maintenance cost

Electric heating equipment generally will not require much attention and supervision and their maintenance cost is almost negligible.

Modes of heat transfer

Heat transfer occurs basically in three modes

1). Conduction

2). Convection

3). Radiation

Conduction

Conduction is the mode of heat transfer occurs from one part of a substance to another part of within the substance itself or with another substance which is placed in physical contact. In conduction there is no noticeable movement of molecules

Convection

Convection heat transfer occurs within a fluid itself and it is carried out by transfer of one fraction of the fluid to the remaining ~~fluid~~ portion. Hence unlike conduction, transfer of molecules occurs during convection.

Radiation

In radiation, heat is transferred in the form of radiant energy or wave motion from one body to another body. No medium for radiation to occur. The rate of heat radiation that can be emitted by a surface at a thermodynamic temperature is based on Stefan – Boltzman law.

Methods of electric heating

- Electric heating
  - Power frequency heating
    - Resistance heating
      - Direct resistance heating
      - Indirect resistance heating
      - Infrared (or) radiant heating.
    - Arc heating
      - Direct Arc heating
      - Indirect arc heating
    - Electron bombardment heating
  - High frequency heating
    - Induction heating
      - Direct induction heating
      - Indirect induction heating
    - Dielectric heating

Resistance heating

In this method of heating, current is passed through the body to be heated. The resistance offered by the body to the flow of current produces ohmic losses I^2R which results in heating the body.

Where electric current passes through a resistance, power loss takes place there in, which appears in the form of heat

Power loss $= I^2R$ watts

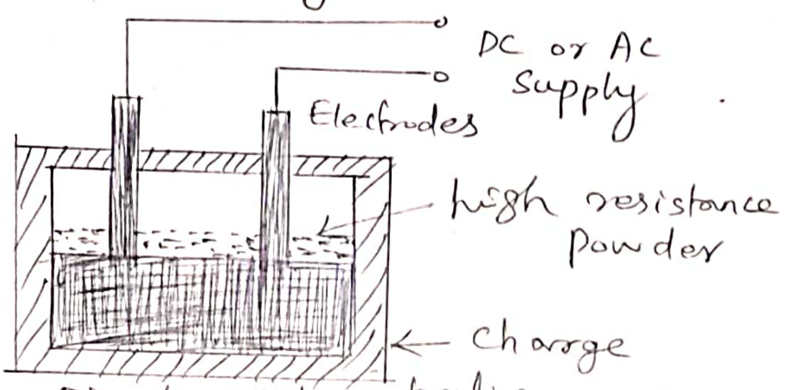
$= I.V$ watts

$= V^2/R$ watts.

Where R is the effective resistance of element.

unlike induction and dielectric heating, resistance heating works equally ~~low~~ well with low voltage and low frequency supply with d.c ②

Direct Resistance heating



Direct resistance heating

In direct resistance heating, electric current passes directly through the material or charge itself. As shown in figure two electrodes are immersed in the charge and connected to the supply in case of availability of d.c or a.c. In case of three phase ac supply three electrodes are immersed in the charge.

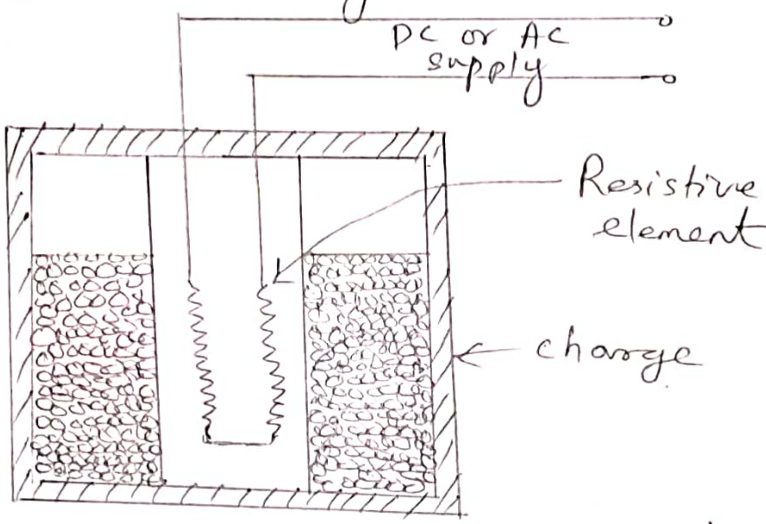
When some pieces of metals are to be heated, some highly resistive powder is sprinkled over the surface of pieces to avoid direct short-circuit.

The current flows through the charge and heat is produced. This method is most efficient since heat is produced in the charge itself.

Automatic temperature control is not possible, because here current is not variable. However, uniform and high temperature can be obtained. This method of heating is used in salt bath funaces and in the electrode boiler for heating water.

Indirect resistance heating

In this method, the current is passed through a high resistance wire known as heating element. The heat produced due to I^2R loss in the element is transmitted by radiation or convection to the body to be heated.



Applications are room heaters, in bimetallic strip used in starters, immersion water heaters and in domestic and commercial cooking and salt bath furnace.

This arrangement is shown in figure. It provides a uniform temperature and automatic temperature control is possible.

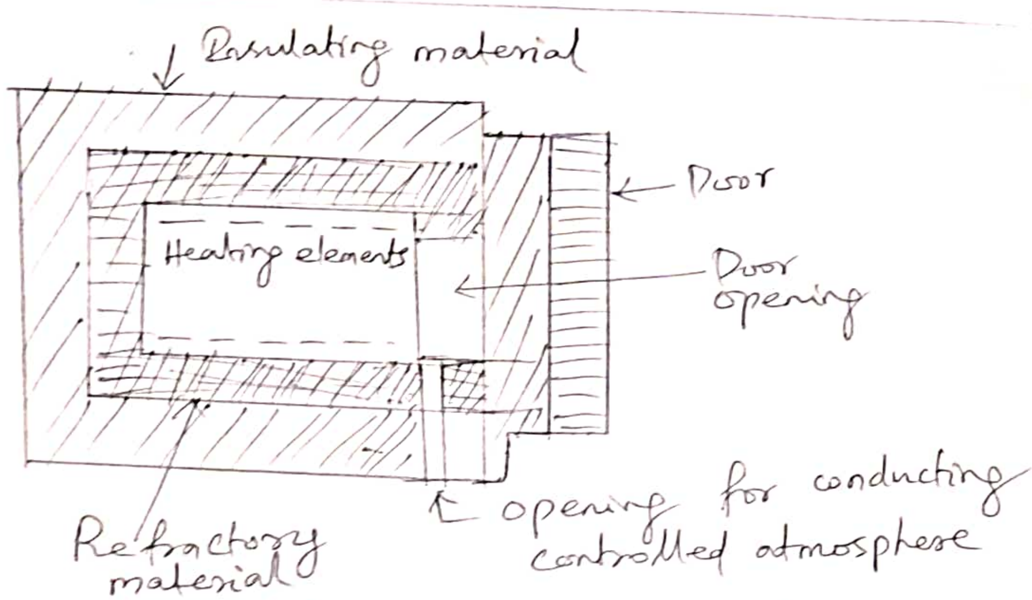
Resistance ovens and Furnaces

According to their operating temperature resistance furnaces are classified as

a) low temperature furnaces (0 – 300°)

b) medium temperature furnaces (300 – 1050°)

c) high temperature furnaces (1050°c – 1350°c)



The resistance furnace is an enclosure with a refractory lining: a surrounding layer of heat insulation and outer casing of steel plate, bricks or tiles. The inside portion of a heating chamber are made to suit the character of the charge and type of furnace or oven. The nature of material required for the insulation is determined by the maximum temperature of the inner face of the layer of insulation of a heating chamber. The heating elements are mounted on top, sides or bottom of the oven.

Temperature Control of Resistance furnaces (oven)

Temperature control is necessary in resistance ovens/furnaces. Temperature may be kept constant or varied according to the requirements. Control may be manual or automatic. Heat developed depends upon I^2Rt. So there are three ways by which temperature can be controlled.

i) Voltage or current

By varying voltage across element

a). Using auto-transformer or induction regulator

b). By series impedance

c). By variable voltage supply.

ii) Time

Periodically switching on and off the electric supply

iii) Resistance

a). By variable number of heating element

b). By series parallel or star delta arrangement of elements.

The above mention methods are used to control the heat loss in the oven. Voltage can be varied by using tapped transformer for supply to the oven or by using a series resistance so that some voltage is dropped across this resistor.

An on-off switch can be used to control the temperature. The time for which the oven is connected to the supply and the time for which it remains isolated the from the supply will determine the temperature. The ratio of $\frac{\text{Time of the switch is on}}{\text{Total time for on-off cycle}}$ is an indication of temperature rise.

Infra-Red or Radiant heating

In radiant heating, the elements are of tungsten operating about 2300°c as at this temperature a greater proportion of infra-red radiation is given off.

Heating effect on the charge is greater since the temperature of the heating element is greater than in the case of resistance heating. Heat emission intensities upto 7500 watts/sqm can be obtained leading to heat absorption upto 4300 watts/sqm. This reduces the time taken by various drying processes

Advantages of Radiant heating

- Rapid heating
- Compactness of heating units
- flexibility
- Safety

Applications

- Pan stoving
- Drying of radio-cabinets and wood furniture
- Preheating of plastics prior to moulding.
- softening of thermo-plastic sheets
- Drying of pottery, paper, textiles etc.

For obtaining best results, the infra-red lamps should be located at a distance of 25-30 cm from the object to be heated.

Properties of heating material

The material of the heating elements should possess the following desirable properties

i). **High resistivity** : should have high specific resistance so that the overall length to produce a certain amount of heat may be smaller

ii) **High melting point** : Should have a high melting point so that high temperatures can be produced without damage the life of element.

iii) **Free from oxidation** : should be able to resist oxidation at high temperatures, otherwise its life will be shortened

iv) **Low temperature coefficient** : Should have a low temperature coefficient so that resistance remains constant even with increase of temperature. This helps in accurate control of temperature.

v). **Positive temperature coefficient of resistance**

If the temperature coefficient of the resistance of heating element is negative, its resistance will decrease with rise in temperature and it will draw more current

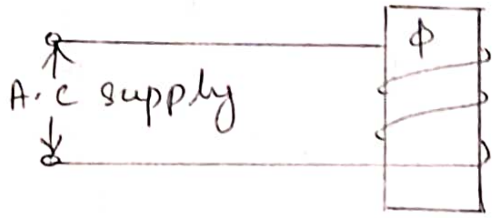
vi) **Ductile** : Since the material of the heating elements has to have convenient shapes and sizes, it should have high ductility and flexibility.

vii) **Mechanical strength** : The material of the heating element should posses high mechanical strength of its own.

Induction heating

Induction heating process makes use of currents induced by electromagnetic action in the material to be heated.

Basic principle of induction heating



It works on the principle of electromagnetic induction as same as a transformer. Figure shows metal disc surrounded by a copper coil in which a.c supply is flowing. This disc has a finite value of diameter and thickness and is spaced a given distance from the coil and concentrate to it.

The current flows on the outer surface of the metal disc, heats this surface. The current flow is restricted axially to that surface of the metal which is contained within the turn or turns of the heating coil and it may be a single turn or a multiturn coil. The heat is generated within the metal without any physical contact between source of electrical energy and the metal being heated.

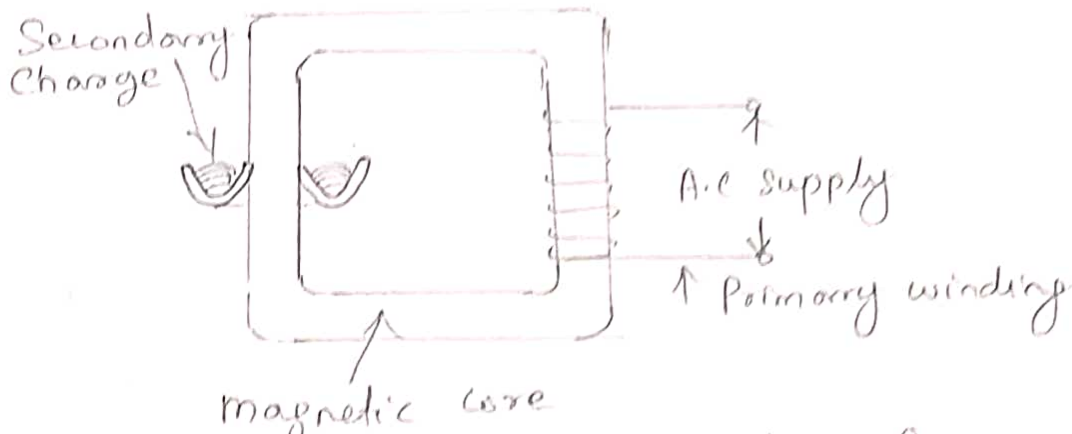
Types of Induction furnaces

1). Core type or Low frequency induction furnaces
   a) Direct core type
   b) Indirect core type
   c). Vertical core type or Ajax-Wyatt furnace
2). Coreless type or High frequency induction furnaces

Core type furnaces

It is like a transformer. The charge acts as the secondary winding and consists of one turn only formed by the metal to be melted.

a). Direct core type induction furnace



Direct core type induction furnace

Figure shows the furnace consisting of an iron core, insulating material and primary winding connected to an a.c supply.

The current in the charge is very high, of the order of several thousand amperes. Electro-magnetic forces are setup by the high current in the molten metal

Attraction is produced between adjacent particles in which current flows in the same direction resulting in pinch effect. Current may be interrupted by these forces which cause contraction. But when the current is interrupted these forces vanish and the metal may flow again.

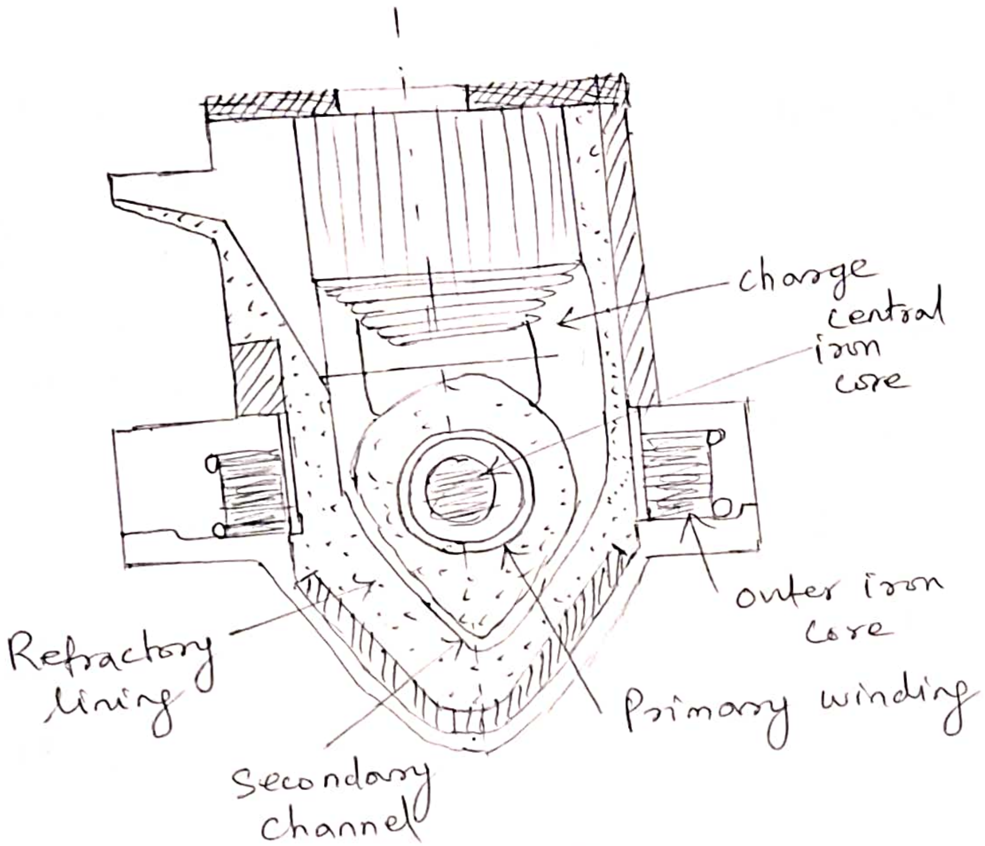
The pinch effect depends upon frequency and the power consumed. Therefore, such furnaces are operated at 25 Hz and lower frequencies.

Drawbacks of Direct core type furnaces

1). Due to poor magnetic coupling, leakage reactance is high and power factor is low.
2). Low frequency supply is required and a frequency converter is required
3). Odd shape of crucibles are not convenient
4). Furnace cannot function if the secondary circuit is open it must be closed.

b). Vertical core type or Ajax-Wyatt Induction furnace

The Ajax-Wyatt furnace is an improved version of the direct core type of furnace and overcomes some of the difficulties mentioned. Furnace arrangement is shown in figure



Ajax – Wyatt Furnace

Since it is a vertical core type furnace the tendency of the currents to interrupt the secondary circuit due to pinch effect is avoided due to weight of the charge in the main body of the crucible.

The circulation of the molten metal is kept up round the Vee portion by convection currents and by electromagnetic forces between the currents in the halves of the Vee.

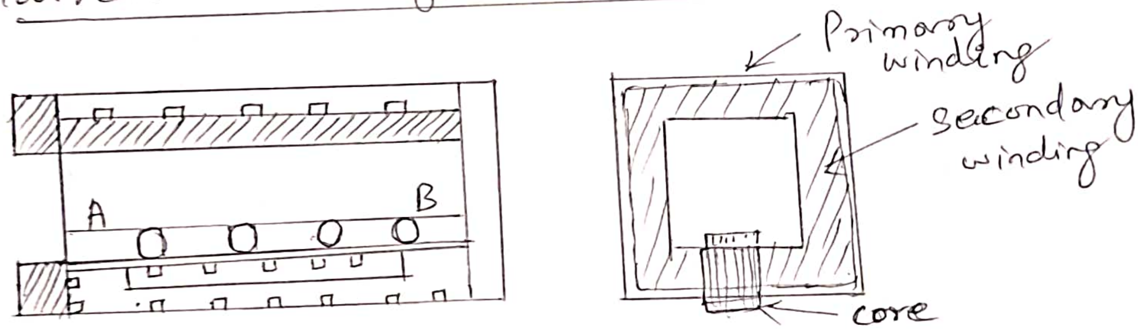
Vee must be kept full of charge in order to maintain continuity of the secondary circuit. For this reason this furnace is useful for continuous operation.

Advantages

- Better power factor 0.8 to 0.83.
- No charges of pinch effect due to heavy weight of the metal over 'Vee' portion.
- It has the shape of crucible.
- Highly efficient heat, low running costs and improved production
- Accurate temperate control, uniform casting and minimum metal losses.

Vertical furnace is used for melting and refining non-ferrous metals such as Brass, Zinc and Tin.

Indirect core type induction furnace



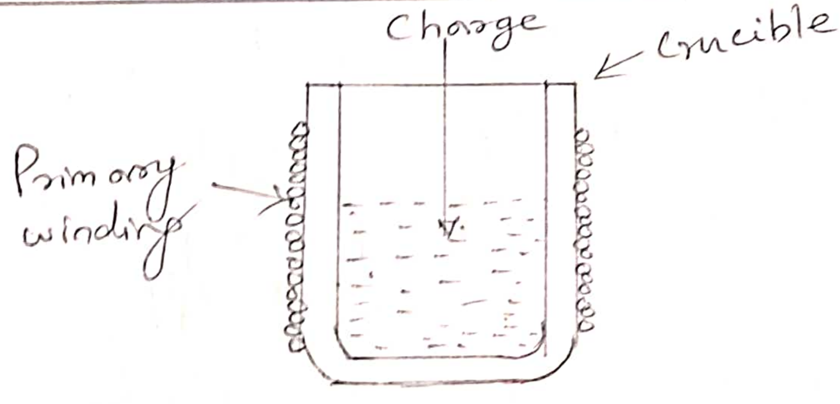
In this type, ~~there is no core~~ ~~in the~~ an inductively heated element is employed to transmit the heat to charge by radiation, as shown in figure.

The secondary winding forms the walls of a metal container and the iron core links the primary as well as secondary winding.

The AB part of the magnetic circuit is situated in the oven chamber and made from a special alloy which loses its magnetic properties at a particular temperature and regains them when cooled approximately to the same temperature.

The oven temperature is thus limited to the critical value without the use of external control equipment. The bar AB is made detachable, so that it can be replaced by other showing different critical temperature ranging between 400 and 1000°C.

Coreless induction furnace



In this type there is no core and thus the flux density is low. For compensating this, the primary current is applied to the primary coil should have sufficient high frequency.

The furnace consists of a ceramic crucible cylindrical in shape enclosed within a coil which forms the primary of transformer and the charge in the crucible forms the secondary of the transformer.

The flux produced by the primary winding sets up eddy currents in the charge which flow concentrically with those in the primary winding. These currents heat up the charge to the melting point and provide stirring action to the charge.

The charge need not be in the molten state at the start as was required in case of direct type furnace. The crucible and coil are relatively light in construction and could be conveniently tilted for pouring.

Since the frequency of supply is very high, the skin effect in the primary coil increases the effective resistance of the coil and hence the copper loss tends to be high and artificial cooling is necessary.

The coil is made of hollow copper conductors through which cooling water can be circulated. The stray magnetic field due to the current in the primary coil may induce eddy currents

(18)

in the metal supporting structures and cause overheating.

Advantages of Coreless induction furnace

- Precise control of power
- Fast in operation
- The crucible of any shape can be used
- No dust, smoke and noise
- Erection cost and operation cost are low
- Intermittent operation possible without any loss in time for warming

Applications

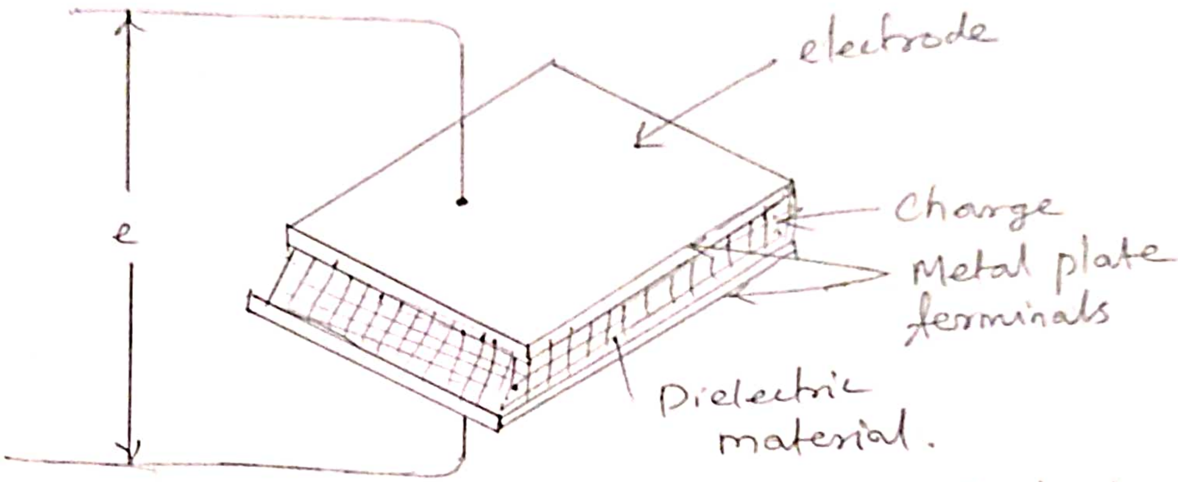
Coreless furnaces are used for steel production. They are also used for melting of non-ferrous metals like brass, bronze, copper, aluminium, magnesium along with various alloys of these elements. It is widely employed for various industrial activities like soldering, braking, hardening and annealing, drying paints etc.

Dielectric heating

Principle

When a Ferro-magnetic material is subjected to alternating magnetic field, it gets heated up due to eddy currents induced in the material and the hysteresis loss in the material. The hysteresis loss is due to reversal of magnetic field which brings about magnetic molecular friction and results in heating the material.

When a insulating material is subjected to an alternating electric field, the atom gets stressed and due to inter-atomic friction heat is produced. This loss is known as dielectric loss.



Dielectric heating is employed for heating non-metals like wood, plastics etc. The frequencies employed between 10 and 30 MHz and the voltage upto 20 kV. Arrangement of dielectric heating is shown in figure.

When a capacitor is subjected to an a.c supply, the current drawn by it is never leading the voltage exactly by 90°. The angle between the current and voltage is slightly less with the result that there is a small in phase component of the current which produces power loss in the dielectric of the capacitor, forms dielectric loss.

At higher frequencies the loss becomes large enough to heat the dielectric. The material to be heated is placed between two electrodes which may be two parallel plates across which high frequency voltage is applied. The material acts as the dielectric between the two electrodes of view of cost, dielectric heating is similar to induction heating.

Advantages

- Uniform electric field, uniform heat
- Higher quality of products.
- Economic, easy and automatic
- Heat takes place in the material itself

Applications

Wood processing, coffee roasting, food processing, choclate roasting, plywood industry, bakeries, book binding, drying in textile mills, plastic industry, removal of moistures from oil emulsions, electro medical application.

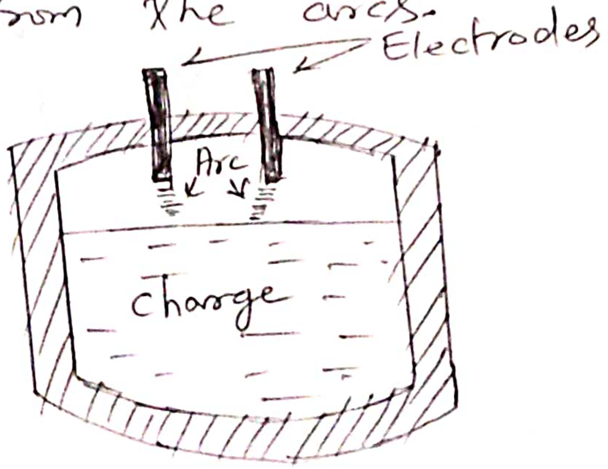
Arc Furnaces

Arc is the flow of current through an air gap between two conducting bodies called electrodes. An electric arc provides a large quantity of power in a small volume. Heat developed at a high temperature of about 3500°C from carbon arc, forms a good heating source. This principle is used in electric arc furnaces. The length of the arc can be varied by controlling the position of the electrodes. These are two types of furnaces

1). Direct arc furnace
2). The indirect arc furnace

Direct Arc Furnace

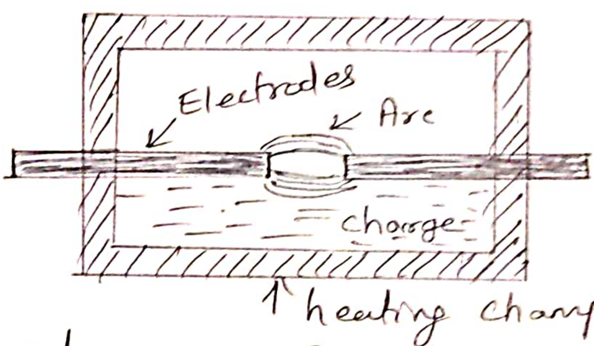
In this, arc or arcs are established between electrodes and charge. Electric current flows through the body of the charge, developing heat due to electrical resistance of the charge in addition to the heat radiated from the arcs.



Direct arc furnace is shown in figure. In case of single phase arc furnace two electrodes are taken vertically downword through the roof of the furnace to the surface of the charge and in a 3 phase furnace three electrodes put at the corners of an equilateral triangle, project on the charge through the roof and three arcs are formed. The current passing through the charge develops electromagnetic field and necessary stirring action is automatically obtained by it uniformly.

Commonly used for production of steel. Capital cost is high. Usual sizes of such furnace is between 5 and 10 tonnes. The power factor is about 0.8 lagging

Indirect Arc Furnace



Indirect arc furnace is shown in figure. In this kind, electrodes are inserted from the sides and the heat produced is transmitted by radiation to the charge. As there is no inherent stirring action, the furnace should be rocked or shacked manually. This furnace is used for only single phase supply with capacity upto 100 tones. This furnace is rocked throughly to ensure that the metal will cover the refractory lining and prevent it from reaching high temperatures. Power factor is 0.87 ~~efficiency~~ efficiency 70%.

Advantages

high meting speed, flexibility, economy, low metal losses.

Applications

Melting of non-ferrous metals like copper, bronze, gun metal, nickel alloys etc. Energy used per tonne is 500 - 800 kW.

Electric welding

It is the process of joining two pieces of metal or non metal at faces rendered plastic or liquid by the application of heat or pressure or both. Filler material may be used to effect the union.

Types of welding process

1). Gas welding

a) Oxy acetyline

b). Air acetylene

c). Oxy hydrogen

2). Resistance welding

a). Butt welding b) Spot welding
c). Projection welding d) Seam welding
e) Percussion

3). Arc welding

a). Carbon arc welding b). Metal arc welding
c). Gas metal arc welding d). Gas tungsten arc welding. e). Atomic hydrogen arc welding
f). plasma arc g) Sub merged arc
h) Flux cored arc i). Electro slag

4). Thermit welding

5). Solid state welding

a) friction b). Ultrasonic
c). diffusion d). explosive

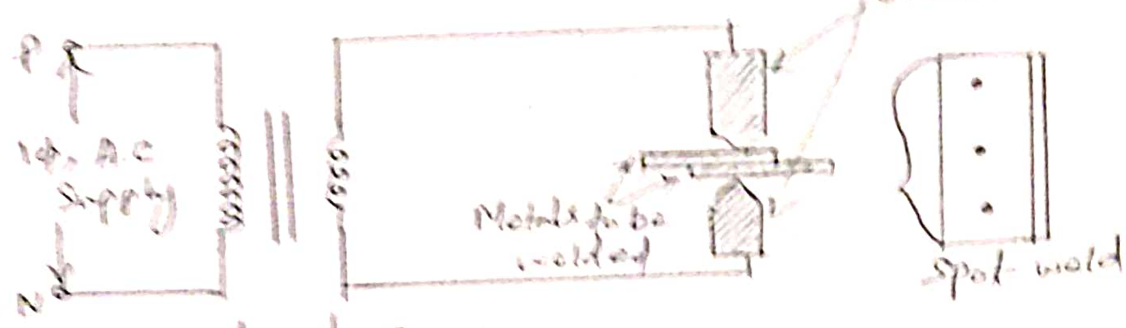
Types of resistance welding

The various types of resistance welding are

1). Resistance spot welding } Lap joints used
2). Resistance seam welding
3). Resistance projection welding
4). Resistance butt welding i) upset welding } Butt joints used
ii) Flash butt welding

5). Percussion welding

1). Spot welding



The arrangements of spot welding is shown in figure. It is the most widely used from of resistance welding. It's simplest version consisting of clamping two or more pieces of sheet metals between two copper or copper-alloy welding electrodes and passing electric current of sufficient magnitude through the pieces so that proper welding can be obtained.

Applications

Spot welding is widely used for fabricating sheet metal products, attaching handle to stainless-steel cookware, rapid spot welding of automobile bodies

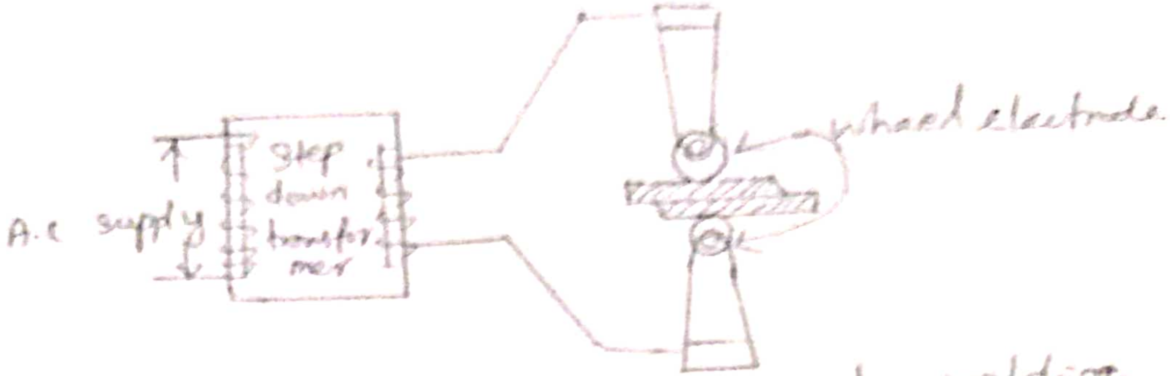
Advantages

1). High production rate 2). Very economical process 3). High skill not required
4). Dissimilar metals can be welded.
5). Small heat affected ~~area~~ area.

Disadvantages

1) Suitable for thin sheets only
2) High equipment cost

2) Seam welding



If the spots of the spot welding are spaced so closely that they overlap each other. Seam welding arrangement is shown in figure. Wheel or roller types of electrodes are used. The mechanical pressure of the electrodes on the work is kept constant. Intermittent current is used, the current being on for a definite time and then off for another fixed interval. This process can produce continuous pressure tight seams at high speeds.

Applications

Fabricating all types of tanks, exhaust systems, barrels, ~~etc~~ transformers, refrigigerators, evaporators, condensers, oil switches

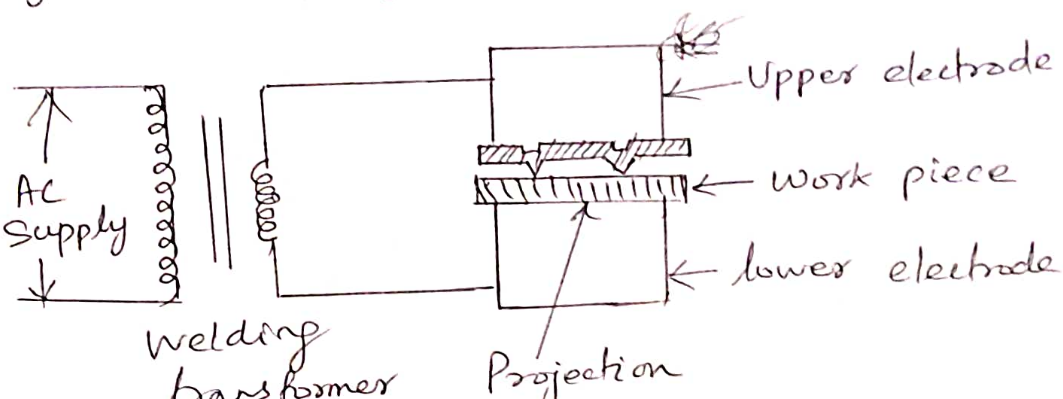
Advantages

1). Materials from 0.13 mm thickness can be welded

2). Almost all types of materials can be welded.

3). The combination of high frequency current and high welding speed produces a very narrow heat affected zone.

3) Projection Welding



It is the modified form of spot welding. Projection welding consists of forming slight projections on the sheet of metal. The projections are accurately formed in precise locations on the metal by a special set of dies. After the projections are formed, the raised portions on one piece are pressed into contact with another piece, while at the same time a heavy current is passed through the two pieces.

When these raised portions touch the second sheet of steel, as they are clamped by the electrodes in a projection welder and the current is applied, current flows at the points heat and fuses the two pieces together.

Projection welding is used for steel radiator, coupling elements, brake shoes, tin plate, tank handle etc. The metal that can be projection welded most satisfactorily is low carbon steel with 0.2% maximum carbon.

Advantages

- More than one spot weld can be made in a single operation
- Welding current and pressure required is less.
- Suitable for automation.
- Filler metals are not used. Hence clean weld joints are obtained.

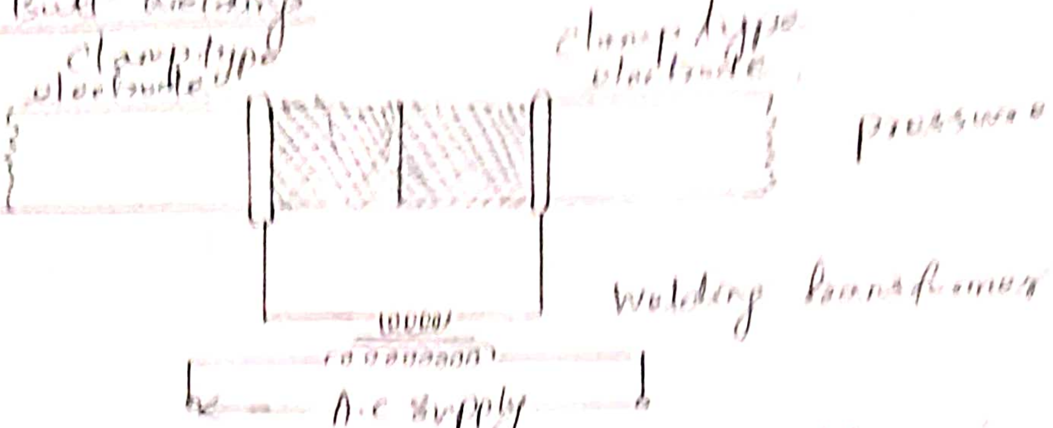
Disadvantages

- Projections cannot be made in thin work pieces.
- This work pieces cannot withstand the electrode pressure.
- Equipment is costlier.

Applications

- Nutts, bolts can be attached to other metal parts by projection welding.

(4). Butt welding

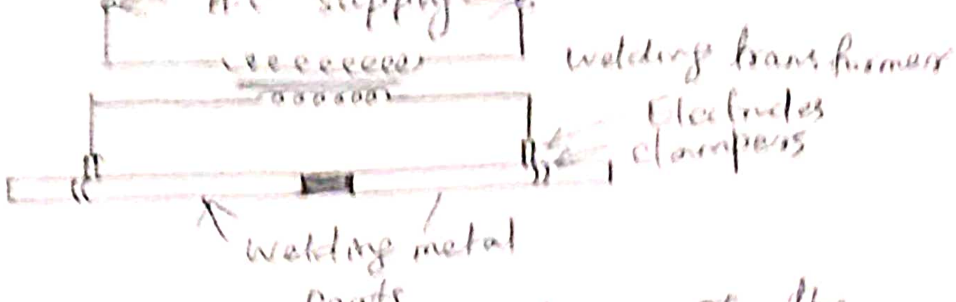


The arrangement for butt welding is shown in figure. Rods, pipes and wires are welded in this way. One part is held in a fixed clamp and the other is held in a moving clamp. The two parts are brought together and pressure is applied along the axial direction by a spring. A heavy current is passed from the welding transformer which creates the necessary heat at the joint due to the comparatively high resistance of the contact area. Due to the pressure of the spring molten metal is forced out producing a bulged joint.

The difference between spot welding is, in butt welding, instead of electrodes the metal parts that are to be joined or butted together are connected to the supply.

a). Upset butt welding

In upset butt welding, the two metal parts to be welded are joined end to end and are connected across the secondary of a welding transformer as shown in figure

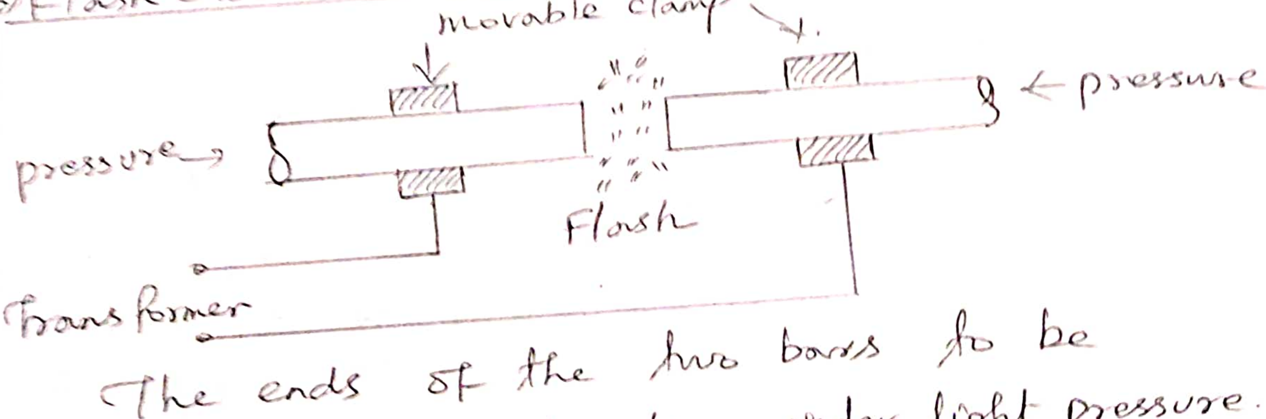


Due to the contact resistance of the metals to be welded, heating effect is generated in this welding. When current is made to flow through the two electrodes, heat will develop due to the contact resistance of the two pieces and then melts. By applying high mechanical pressure either manually or by toggle mechanism, the two metal pieces are pressed.

Applications

Non-ferrous materials for welding bars, rods, wire, steel rails whose cross sectional area is as much as $6.25\ cm^2$.

b) Flash-Butt welding



The ends of the two bars to be welded are put together under light pressure. Arcing at the joint is allowed to take place.

Flashing continues till the two ends reach welding temperature when pressure is applied. A weld having a thin fin around the joint is obtained which is easily removed to produce a flash weld.

Most metals except lead, zinc, antimony, bismuth and their alloys can be flash welded.

Advantages of flash butt welding over upset welding

1). less equipment of power

2). When the surfaces being joined, it requires only less attention.

3). Weld is obtained so clean and pure.

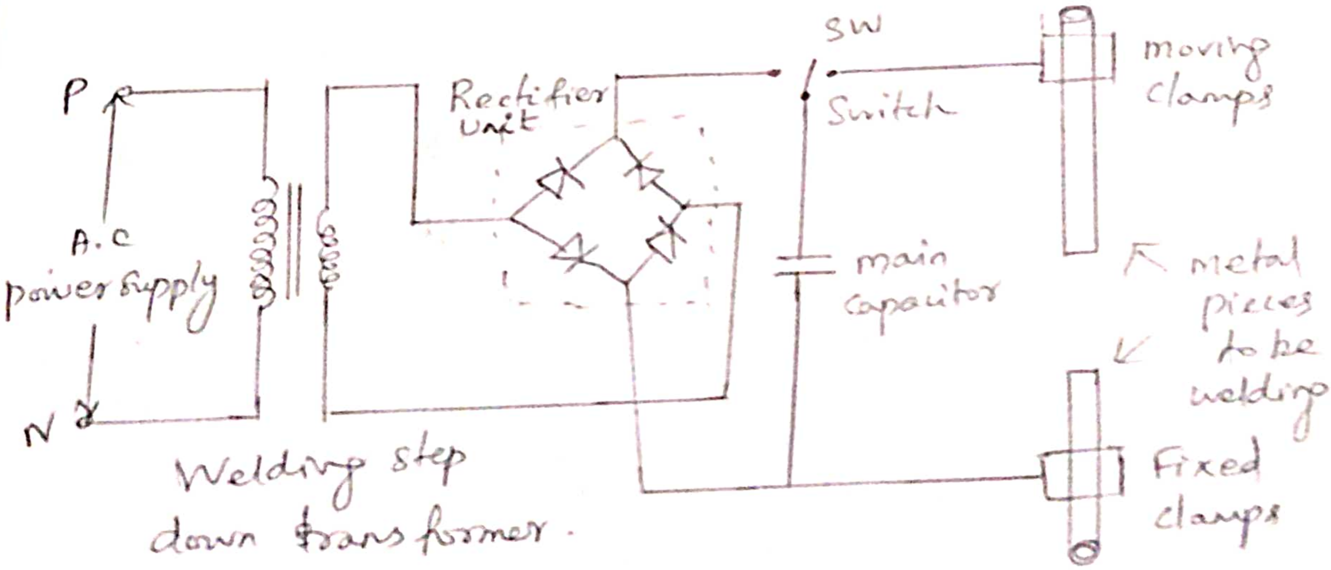
Applications

Thick pipes, ends of band saws, frames, aircraft landing gears are produced by flash welding.

Percussion welding

It is a very fast method of welding. Percussion welding arrangement consists of one fixed holder and the other one is movable. Two pieces to be welded are held apart, with the help of two holders. When the movable clamp is released, it moves rapidly carrying the piece to be welded. There is a sudden discharge of electrical energy, which establishes an arc between the two surfaces and heating them to their melting temperature.

When the two pieces are seperated by a distance of 1.5 mm apart. As the pieces come from in contact with each other under heavy pressure, the arc is extinguished due to percussion blow of the two parts and the force between them affects the weld. The precussion welding can be obtained in two methods, one is capacitor energy storage system and other is magnetic energy storage system. The capacitor energy storage system. The capacitor energy discharge circuit for percussion welding is shown in figure



The capacitor C is charged to about 3000 V from a controlled rectifier. The capacitor is connected to the primary of welding transformer through the switch and will discharge. The discharge will produce high transient current in the secondary to join the two metal pieces.

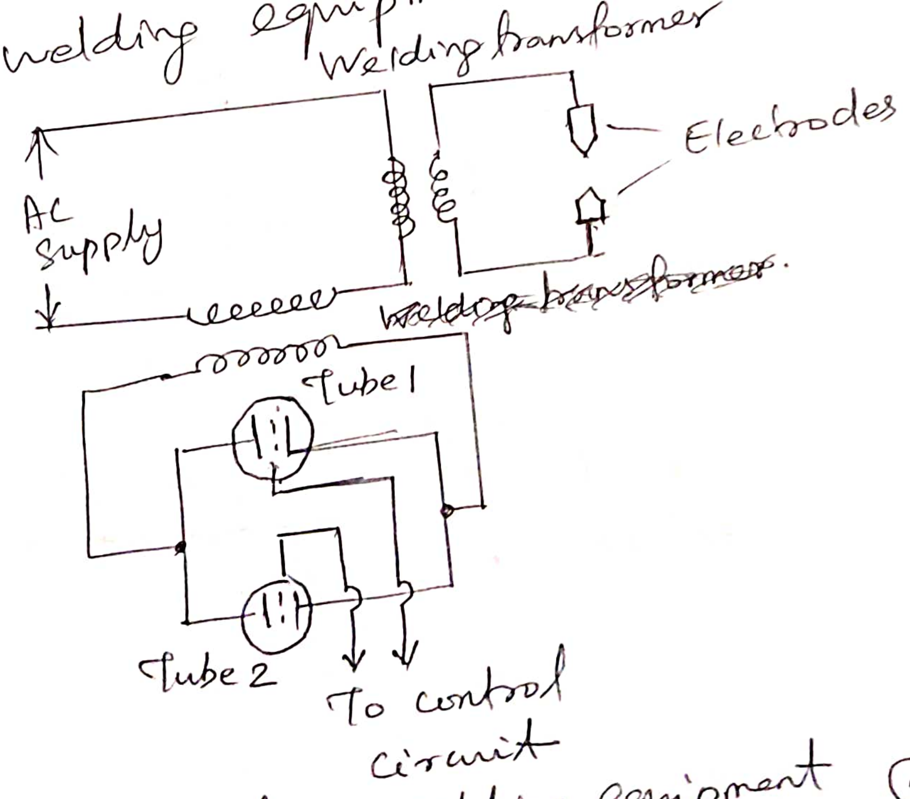
Applications

1). It is useful for welding satellite tips to tools, cast iron to steel, silver contact tips to copper.

2). copper alloys, aluminium alloys and nickel alloys are percussion welded.

Control of Resistance welding

The arrangement for control circuit of welding equipment is shown in figure



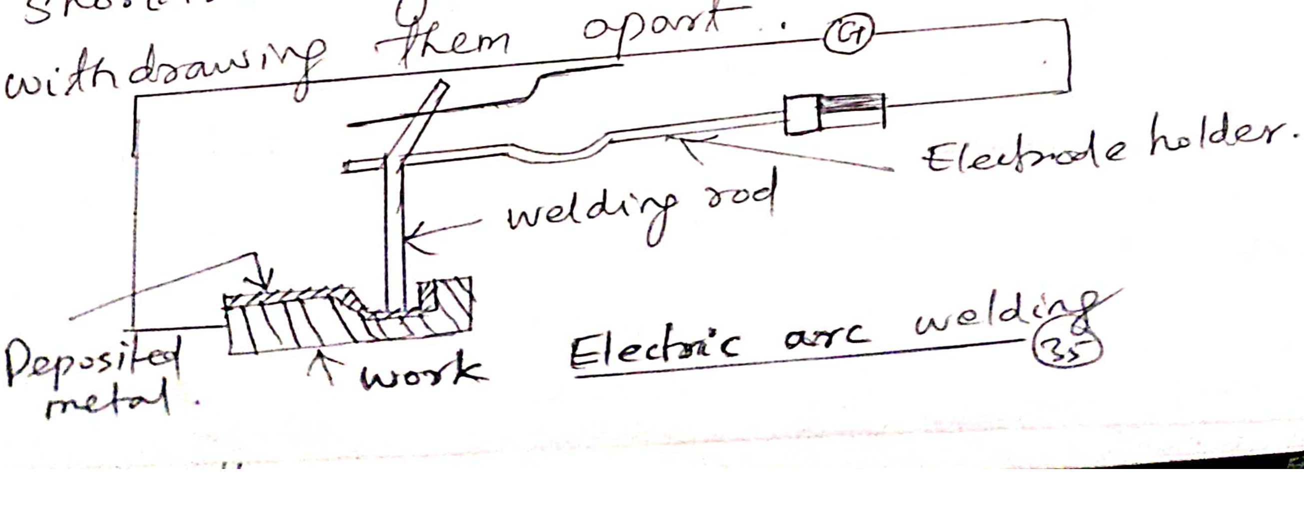
Constant time welding equipment - electric control

When the tubes are conducting since the series transformer secondary is almost short circuited, the series transformer impedance is very low and the whole of the supply voltage is available across the primary of the welding transformer.

When the valves do not conduct, the series transformer primary winding offers high impedance in the circuit of the welding transformer and the current is reduced to a negligibly low value. The grids of the tubes are controlled by other valves so as to achieve proper timing. This method of control is ~~Conts~~ Constant time equipment control method.

Arc welding

An electric arc is the flow of electric current through gases acompained by heat and bright glow due to ionization and dissipation of energy of the surrounding medium. The electric arc is struck by shortcircuiting two electrodes and then withdrawing them apart.



Electric arc welding

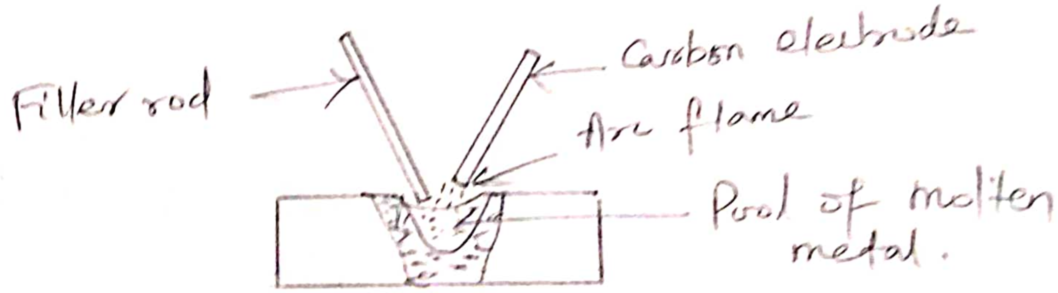
Electrons emerge from separated tip depending on its polarity, move to the other tip by colliding and ionizing the surrounding medium in between the tips.

The arc is of negative resistance characteristics, ie with increase of arc current, voltage across it decreases, ie resistance of the arc decreases. ie Increase of arc length also reduces the arc and further increases the resistance.

Types of arc welding

1). Carbon arc welding
2). Metal arc welding
3). Atomic hydrogen arc welding
4). Inert gas metal arc welding
5). Submerged arc welding

1). Carbon arc welding



The electrode is of carbon which is made negative with respect to work if dc is used if the carbon electrode is made positive, the carbon particles have a tendency to go into the welded joint and cause brittleness

From the figure the work is connected to negative and the carbon rod or electrode connected to the positive of the electric circuit. Arc is formed in the gap filling metal is supplied by fusing a rod or wire into the arc by allowing the current to jump over it, ~~and~~ it produces a porous and brittle weld because of inclusion of carbon particles in the molten metal. It is therefore used for filling blow holes in the castings. The voltage required for striking an arc with carbon electrodes is about 30 volts (A.C) and 40 volts (D.C)

Advantages

1). The heat developed during the welding can be easily controlled by the length of arc

2). It is quite clean, simple and less expensive.

3). Easily adoptable for automation.

4). Both ferrous and non ferrous metals can be welded.

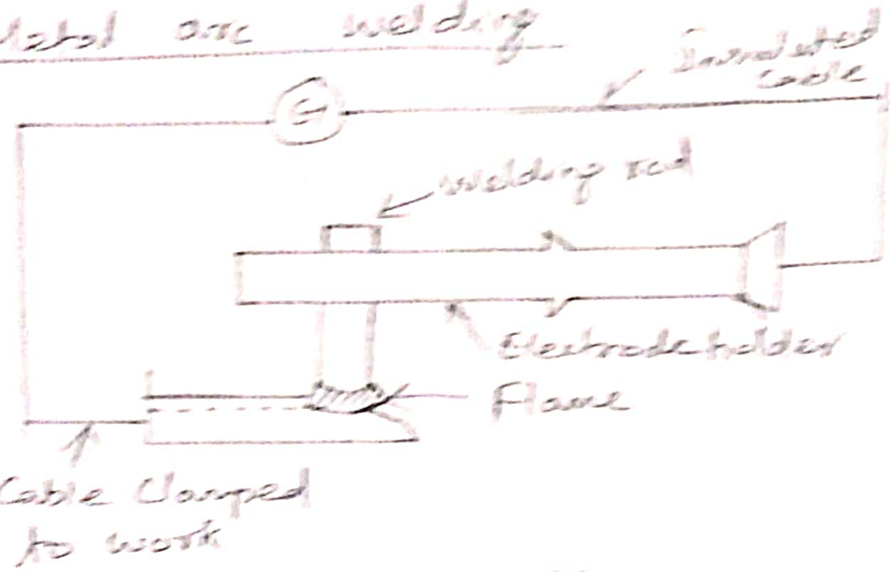
~~Dis adva~~

Disadvantages

1). High input current

2). A seperate filler rod has to be used if any filler metal is required

2) Metal arc welding



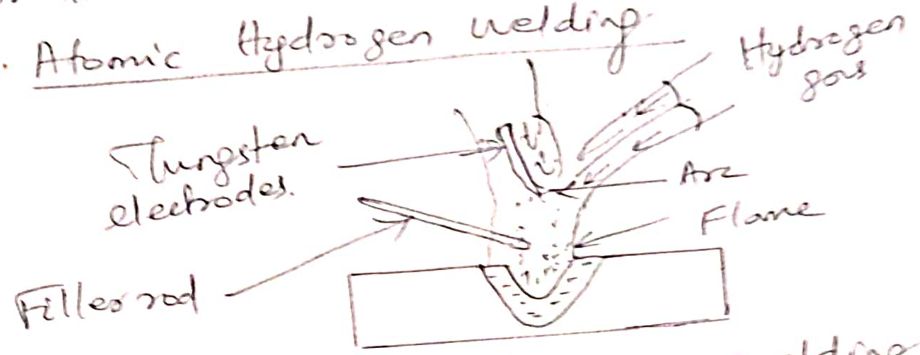
Metal arc welding arrangement is shown in figure. Current flows via electrode through the arc to the work and back to the supply via the earth connection. Due to the heat generated by the arc, a little portion of the work melts as also the tip of the electrode. When the electrode is removed the metal cools and solidifies.

In metal arc welding the electrodes used must be of the same metal as that of the work piece to be welded. The electrode itself forms the filler metal. An electric arc is stuck by bringing the electrode connected to a suitable source of electric current.

The arc produced between the workpiece and the electrode result high temperature of the order of about 2400°C at negative negative metal electrode and 2600°C at positive base metal or work piece.

Both AC and DC can be used for metal arc welding. The voltage required for the DC metal arc welding is about 50-60 V and for the AC metal arc welding is about 80-90 V.

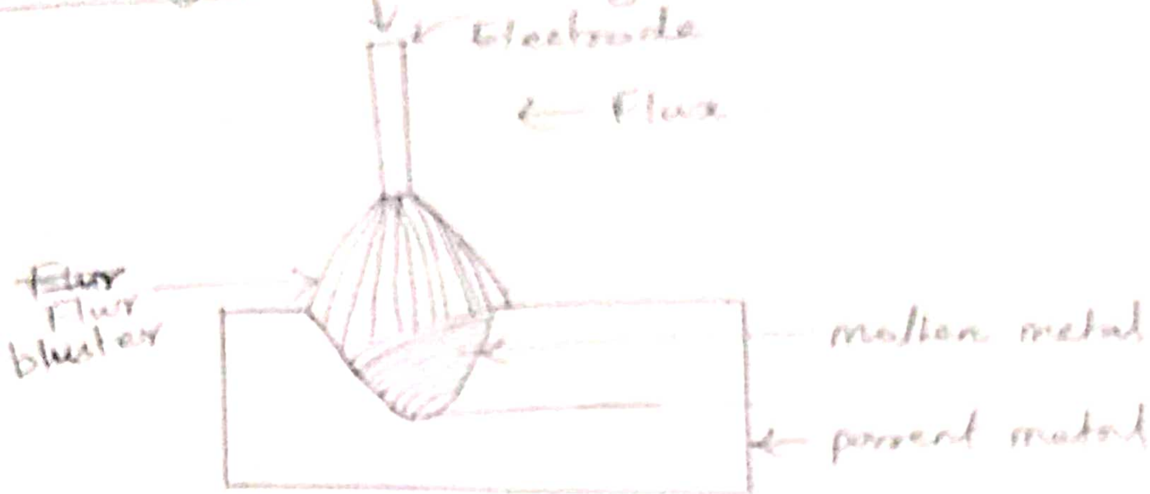
3). Atomic Hydrogen welding



Atomic hydrogen welding

From the figure, In this system heat is obtained from an alternating current arc drawn between two tunsten electrodes in an atmosphere of hydrogen. As the hydrogen gas passes through the arc, the hydrogen molecules are broken up into atoms and they recombine on contact with the cooler base metal generating intense heat sufficient to melt the surfaces to be welded, together with the filler rod, if used. The envelop of hydrogen gas also shields the molten metal from oxygen and nitrogen and thus prevents weld metal from deterioration.

(c) Submerged arc welding



The arrangements for submerged arc welding is shown in figure. Electric arc and molten pool are shielded by blanket of granular flux on the work piece. Initially to start an arc, short circuit path is provided by introducing steel wool between the welding electrode and the work piece.

This is due to the coated flux material when cold it is non conductor of the electricity but in molten state, it is highly conductive welding zone is shielded by a blanket of flux, so that the arc is not visible. Hence it is known as 'submerged arc welding'. The arc so produced, melts the electrode, parent the metal and the coated flux, which forms a protective envelope around both the arc and the molten metal.

As the arc in progress, the melted electrode metal forms globules and mix up with the molten base metal, so that weld is completed. In this welding, the electrode is completely covered by flux. The flux may be made of silicate metal oxides and other compounds. Therefore the welding takes place without spark, smoke etc.

Voltage required for the submerged arc welding varies from 25 to 40V current employed for welding depends upon the dimensions of the workpiece. Normally if DC supply is used current is 600 to 1000A, the current for AC is usually 2000 A.

Electric arc welding equipment and power supply

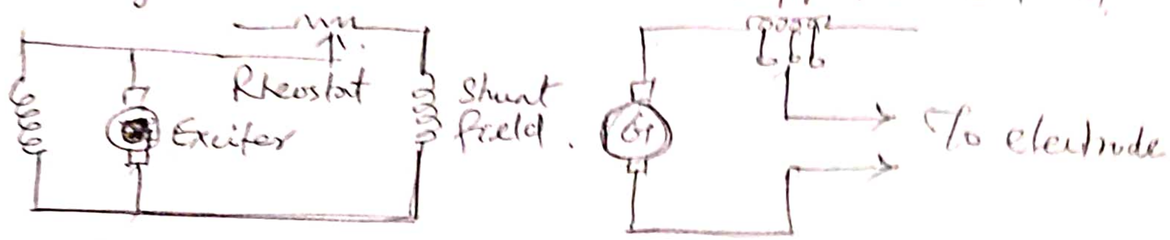
Electric arc welding equipment may be a.c or d.c. The basic requirement is that it should have high open circuit voltage to enable striking the arc. ie 50 to 100 V. A voltage of 20 to 30 Voltage is needed to maintain the arc.

Power supply requirements for (arc) welding equipments

- The open circuit voltage must be sufficient for an arc to strike without difficulty, but safe for the operator below 80 volts.

- The short circuit current must be within limits of safety for generator or transformer windings
- The voltage of the source of power supply should vary rapidly with changes in arc length.
- The wattage of the source of power supply should be sufficient to give the desired arc current

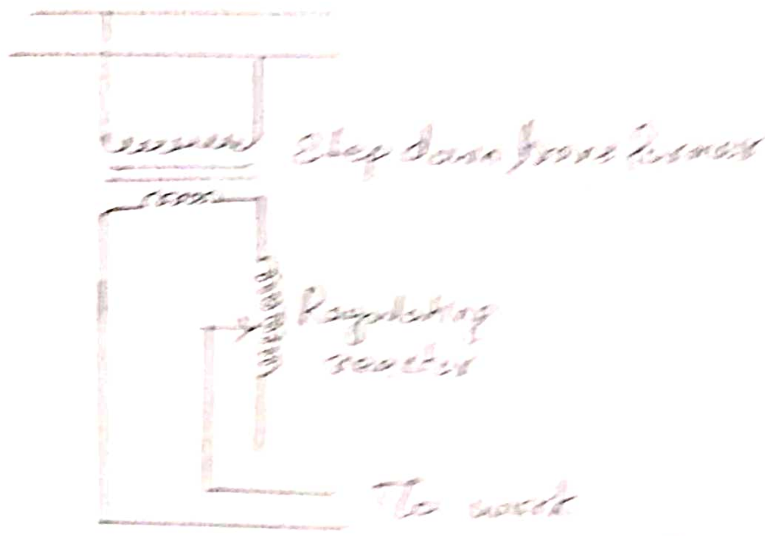
DC welding set



The type of dc welding set is
1). Generator type 2) Rectifier type

In DC welding, the control of the heat generated in the electric arc is by controlling the length of the air gap. When a certain current is selected from the machine, arc gap should be kept constant. If the gap changes the current across the gap, the heat due to welding also changes. The sparking voltage in between 60 and 80 volts.

AC welding set



Single phase or 3 phase step down transformer which provide low voltage power for welding with some means of output control. Here the difference of voltage is absorbed by the reactor. The reactor also stabilizing the arc on account of low power factor.

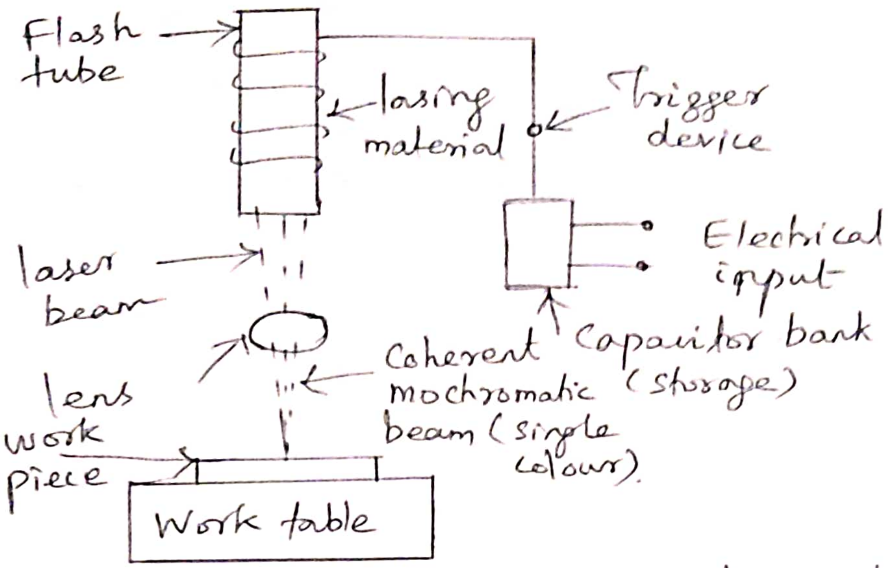
Radiation welding

Radiation welding, heat being generated only ~~being~~ where the focused beam strikes the workpiece. Unlike arc or flame sources, the work is not brought in contact with any heated media, gas or metal vapour, and the processes may be carried out in vacuum or low-pressure systems.

Types

1). Laser beam
2). Arc image
3). Electric beam

1). Laser beam welding



The arrangements of laser beam welding is shown in figure. The laser welding system consists the following
1). Electrical storage unit 2). Capacitor bank
3). Triggering device 4). Flash tube that is wrapped with wire 5). lasing material
6). Focussing lens mechanism. 7). Work table.

When capacitor bank is triggered, energy is injected into the wire that surrounds the flash tube. This wire establishes an imbalance in the material inside the flash tube. Thick xenon is used in the material for the flash tube, producing high power levels for very short period of time.

The flash tubes or lamps are designed for operation at a rate of thousands of flashes per second. By operating in this manner, the lamps become an efficient device for converting electrical energy into light energy, the process of pumping the laser. The laser is then activated. The beam is emitted through the coated end of the lasing material. It goes through a focussing device where it is pinpointed on the workpiece. Fusion takes place and the weld is acomplished.

Advantages

1). This process can be used to weld dissimilar metals.

2). high power density weld process

3). high productivity

4). reduction of scrap and rework

5). reduction of manual labour.

Disadvantage

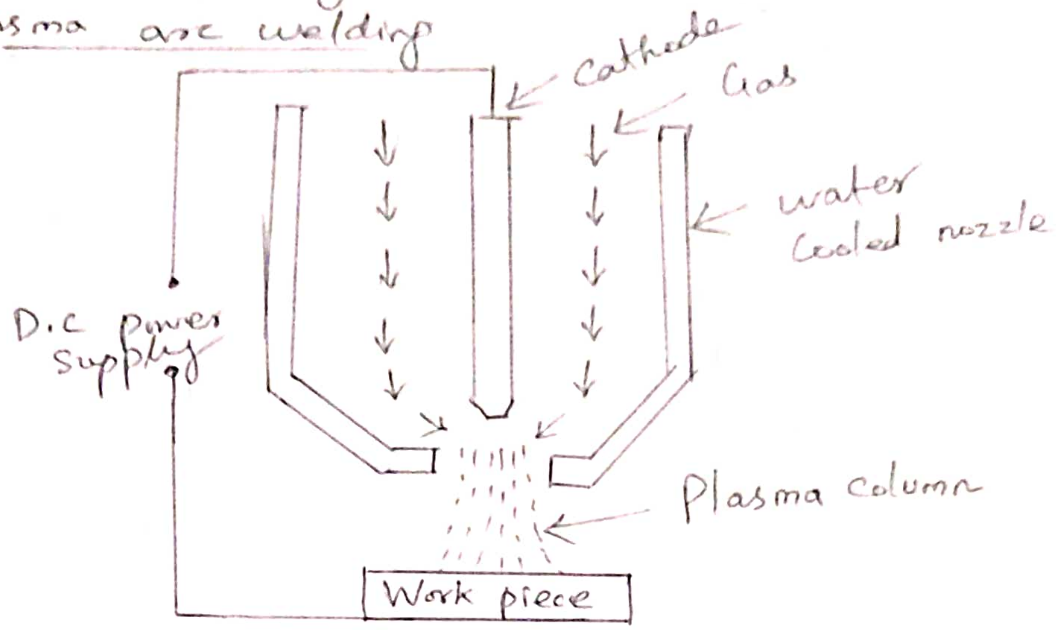
1). Energy losses are high.

Arc Image Welding

Arc image welding, Fusion is acomplished by focussing the image of a high temperature source on the work place. Mirrors are used for this purpose. High pressure plasma arc sources have been developed as the heat source and outputs above

10 KW have been used for welding. Optimal systems with top surface mirrors of high frequency are necessary for focussing

Plasma arc welding



Plasma arc consists of an electronic arc plasma gas and gases used to shield the jet column. Plasma arc welding equipment includes conventional DC power supply with a drooping volt ampere output and with 70 open circuit volts.

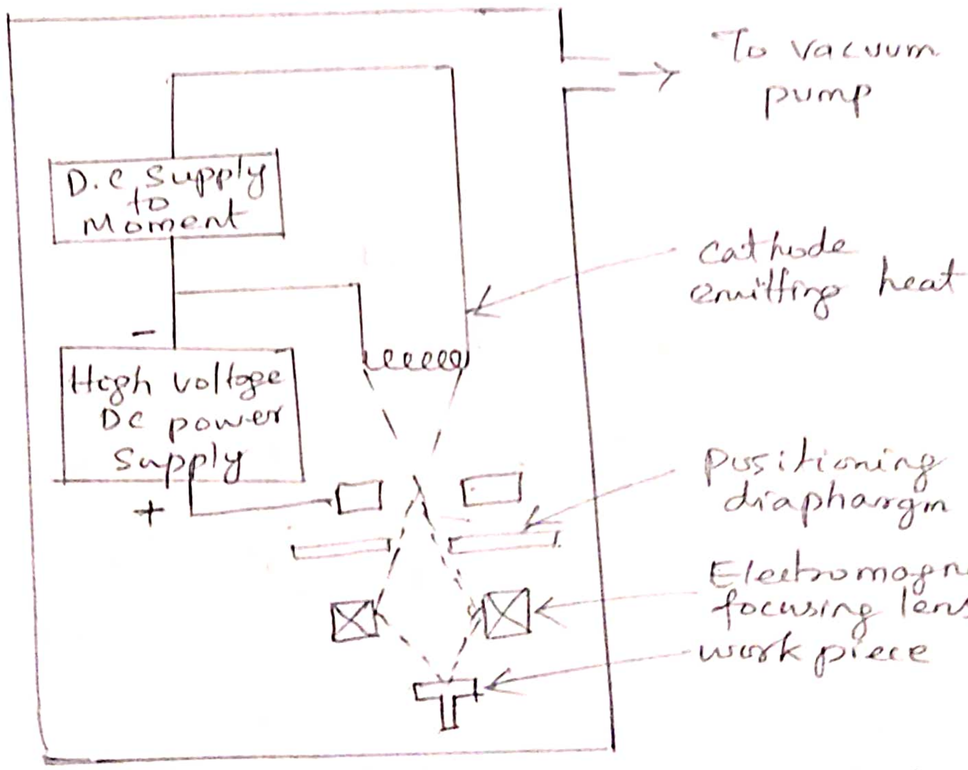
Two main types of torches for welding and cutting with plasma arc

i) transferred arc ii) Non transferred arc

The transferred arc plasma, it has the water cooled nozzle between the electrode and the work. This nozzle constructs the arc, increasing its pressure. The plasma, caused the collision of gas molecules with high energy electron, is then swept out through the nozzle, forming the main current path between the electrode and the workpiece.

The non transferred arc torch extends the arc from the electrode, or the cathode, to the end of the nozzle acts as anode. This type of plasma jet is completely independent of the workpiece, with the power supply contained with the equipment.

Electron beam welding



Electron beam welding is a process involving melting in which the energy is supplied by the impact of focussed beam of electrons. The essential components a welding equipment are electron gun, focussing and beam control system and the working chamber which operates at low pressure.

Electrons are produced by a heated filament or cathode and are given direction and acceleration by a high potential between cathode and ~~electrode~~ an anode placed some distance away. When the fast moving electrons hit, the workpiece releases their kinetic energy as heat in the material to be heated. This heat is utilized to melt the metal.

If this process is carried out in high vacuum, without ~~producing~~ providing any electrodes, gasses or filler metal, pure weld can be obtained. If vacuum was not used, the electron would strike the small particles in the atmosphere, reducing their velocity and also heating ability.

The power released by the electron beam is given by

$$P = nq\nu \text{ volts}$$

$n \rightarrow$ no of charge particles

$q \rightarrow$ charge in coulombs per meter

$\nu \rightarrow$ voltage required to accelerate the electron from rest.

As shown in figure electron beam welding requires electron emitting heating filament as cathode, focusing lens, etc.

Two marks

1). What are the causes of failure of heating elements?

i). Formation of hot spots

ii) General oxidation of the element and intermittency of operation

iii) Embrittlement caused by gain growth

iv) Contamination of element or corrosion

2). What are the properties of heating element material?

i). High resistivity ii) High melting point

iii) Free from oxidation iv) low temperature co-efficient.

3). Compare AC welding and DC welding

Factors	D.C welding	A.C welding
Equipment	Motor-generator set or rectifier is required	Only a transformer is required
Operating efficiency	low	~~[illegible]~~ high 85%
Power factor	high	low
Heating	Uniform	non uniform
No load voltage	low	Too high

4). What are the advantages and disadvantages of Electron beam welding?

Advantages

1). Heat input to the electron beam welding can be easily controlled by varying beam current, voltage, the position of the filament etc.

2). It can be employed for the welding of thick sections due to high penetration to width ratio

3). Narrow electron beam reduces the distortion of workpiece.

Dis advantages

1). The pressure build up in the vacuum champer due to the vapour of the parent metal causes electrical break down.

5). What are the advantages of electric heating?

i) economical

ii) Cleanliness

iii) Absence of flue gases

iv). Ease of control

v). Automatic protection vi) Safety

6). What are the drawbacks of direct core type furnaces?

i). Due to poor magnetic coupling, leakage reactance is high and powerfactor is low

ii) low frequency supply is required and and frequency converter is required
iii) Old shapes of crucibles is not convenient
iv) Furnace cannot function if the secondary circuit is open, it must be closed

7). Mention the advantages of coreless induction furnace
i) Precise control of power
ii) Fast in operation
iii) The crucible of any shape can be used
iv) No dust, smoke and noise
v). Erection cost and operation cost are low

8). What are the applications of coreless furnaces?
Coreless furnaces are used for steel production. They are also used for melting of non-ferrous metals like brass, bronze, copper, aluminium etc.
It is widely employed for various industrial activities like soldering, braking, drying paints etc.

9) What is the efficiency of the oven?

$$\eta = \frac{\text{Heat required to raise the temperature of the charge to the required value}}{\text{Heat required to raise the temperature of the charge to the required value + losses}}$$

The efficiency is between 60 to 80%.

10) What are the types of resistance heating?

refer notes.

11). What are the types of induction heating?

refer notes

12). What are the types of arc furnaces?

refer notes.

13). What are the types of resistance welding?

refer notes

14). What are the types of arc welding?

refer notes

15). What are the types of radiation welding?

refer notes.

UNIT - IV

ENERGY CONSERVATION AND ITS IMPORTANCE

Energy conservation act 2001 and its features - Review of Industrial Energy conservation - Energy conservation in Electrical Industries - Simulation study of energy conservation using power factor controller

Energy conservation act 2001 and its features

Energy conservation act 2001

With the background of high energy saving potential and its benefits, bridging the gap between demand and supply, reducing environmental emissions through energy saving, and to effectively overcome the barrier, the Government of India has enacted the Energy conversion Act - 2001. Indian government enacted this act in response to the potential and benefits of energy conservation. This legislation provides a legislative structure and organisation to achieve the energy efficiency. It successfully bridges the demand-supply gap, saves energy and decreases environmental emissions

This act provided much needed legal frame work and institutional arrangement for embarking on an energy efficiency drive. Under the provisions of the Act, ~~Bee~~ Bureau of Energy Efficiency (BEE) has been established with effect from 1st march 2002 by merging erstwhile energy management centre of ministry of power. The Bureau would be responsible for implementation of policy programmes and coordination of implementation of energy conservation activities.

The objective of EC act is to promote efficient use of energy and its conservation through certain statuory measures to promote conservation of energy and facilitate its efficient use in various sectors of our country.

Important features of energy conservation act 2001

Energy conservation act 2001 empowers the union government and in some instances the state government to:

i). Inform energy-intensive companies, business and commercial buildings that they are designated customers

2). Establish energy usage guidelines and criteria for certain customers

3). Instruct the consumer to hire certified energy managers for energy efficiency.

4) The government should modify energy-saving building codes to reflect regional and local climatic conditions

5). Require commercial building owners to follow energy conservation construction codes

6). Directly required labelling of altered equipment and appliances

7). Energy consumption standards for specified equipment and appliances.

8). Ban the manufacture, sale, purchase and import of not-confirming notified equipment and appliances

9). Under the provision of this act the Bureau of Energy Efficiency (BEE) was established with effect from 01.03.2002.

10). The mission of the BEE is to institutionalize energy efficiency services, promote energy efficiency delivery mechanism and provide leadership for improvement of energy efficiency in all sectors of the economy.

Importance (or Benefits) of energy conservation

1). Energy conservation is critical to conservating non renewable energy resources.

2). Energy conservation will lower the cost of fossil fuels

3). Energy saving would boost the economy by giving customers more discretionary ~~incom~~ income to spend on good and services

4). Scientific research benefits from energy conservation. This is because energy saving allows researchers to undertake more research.

5). Energy conservation is important for environmental protection. It reduces CO_2 and other emissions

6). It reduces the energy bills.

7). It increases competitiveness

8). It increases productivity and profits.

9). It improves quality.

10). It improves energy security.

Initiatives to be taken by government for energy conservation

1). To support energy conservation and efficiency activities and programmes with leadership, policy recommendations and direction

2). To organise and present energy efficiency and conservation policies and programmes to stakeholders.

3). Develop methods and procedures for measuring, monitoring and veryfying energy efficiency results in specific sectors as well as the macro level

4). Leverage multilateral, bilateral and corporate sector. support for the Energy conservation Act and efficient energy use and conservation programs.

5). To show the delivery of energy efficiency services specified under the ECA through public private partnerships.

6). To interpret, develop and manage energy conservation ~~act~~ programmes in accordance with the provisions of EC act.

7). To provide policy recomendations and provide direction to national energy conservation initiatives as well as to coordinate policies and programmes on energy efficiency with shore holders.

8) Implement systems and procedures for ~~very~~ verifying, measuring and monitoring energy efficiency (EE) improvements.

9). To mobilise international, bilateral and private sector support for energy conservation act 2001.

10). To demonstrate EE delivery systems through public private partnerships.

Energy conservation in industries

Energy conservation in small scale industries

i) **Illumination**: Industrial lighting needs range from low levels to high levels needed for precision work. Substantial savings are possible by use of one or more of the following

a) Maximum use of natural light: Installation of fibre glass skylight in the roof are needed for this purpose. Electric lighting is seperated into circuits that are controlled by photo cells. When there ~~are~~ is enough natural light, electric bulbs are turned OFF automatically.

b). Use of high efficiency lamps and luminaires

The efficiency of the bulbs ranges from roughly 10 lumens/watt to about 120 lumens/watt

c). Reduction of illumination to acceptable task levels

It has been discovered that lighting levels excessive in many places and can be simply adjusted without affecting productivity, efficiency or worker health.

d) Improved maintenance and cleaning of lighting equipment and lamps e). Proper lighting control

ii) <u>Electric power distribution</u>

The steps which can be taken in this regard are,

a). <u>Proper design and installation of electric distribution system</u>:

The distribution system of the facility should be designed and installed properly

b). <u>Improvement of overall power factor of installation</u>: It is well understand that a lower power factor results in higher energy losses. Wherever possible, shunt capacitors should be installed to increase power factor.

c). Reduction of peak loads wherever possible.

iii) <u>Selection of drives and equipment and their operation at full load</u>:

The drives and equipment should be chosen based on life cykle costs rather than startup expenses. This type of selection ensures that the most efficient machines are used. Also induction motor is the most widely used AC motor. As a result, induction motors, should be run at full load as often as possible

iv) Testing facilities : Industries will always require testing facilities to put their products through their paces. The use of energy-~~efficient~~ efficient testing methodologies, as well as the potential of combining testing of many times, should be encouraged.

Energy conservation in large scale industries

The conservation of energy in large scale industry as follows,

a). Pulp and paper industry : Some energy conservation measures adopted by some pulp and paper industries are,

Modification of chippers, replacement of batch digesters with continuous digesters, use of medium consistency pumps, uses of falling film evaporators, waste heat recovery, improvement of power factors of electri motors and operation ~~of~~ motors at peak efficiency.

b). Cement industry : optimum layout, use of single stage impact type hammer crushers, use of vertical roller mills and high pressure grinding rolls, use of modern pressure grinding rolls, reduction of exit gas temperature, coat benefication and pre-blending of coal, improved burners and operation optimisation c). <u>Petroleum refinery</u>: The possible measures measures for energy conservation in this industry are,

Adding new heat exchangers to boost the temperature of crude, using air preheaters to exploit the heat of flue gases, using a carbon monoxide boiler to recover the heat content of carbon monoxide, steam re-routing, process adjustments, optimising cooling tower operation.

d). <u>Iron and steel Industry</u>: Improved sintering plant ignition system, sintering plant heat recovery system, optimum combustion control in coke ovens, flue gas heat control, use of ceramic heat exchangers for oxygen gas, slag heat recovery, direct hot charge rolling, use of gas recuperators in reheating furnaces, scrap preheating system in electric furnaces.

<u>Explain the energy conservation technique adopted in lighting system by using energy efficient luminaries and using light controlled gears</u>

<u>Best practices in lighting systems</u>

1). replace tradional flourescent lighting with energy-efficient fluorescent lamps

2). Use compact fluorescent lamps (CFL) instead of incandescent bulbs

3). Use LED panel indication lamps instead of filament bulbs.

4). Use of high frequency (HF) electronic ballasts instead of traditional magnetic ballasts.

5). Usage of high efficiency light sources to reduce lighting energy consumption.

6). Solar lighting systems are a superior option in rural India because they have no moving components, simple, require no maintenance

Energy Conservation measures in lighting systems

1). Using LED bulb as indicator lamps reduces energy usage

2). Use compact fluorescent bulbs instead of incandescent lamps reduces lighting energy consumption by 70%.

3). The use of mirror optic fluorescent bulbs significantly boosts the brightness level.

4). Using HPSV bulbs instead of MPSV lamps cut energy consumption by 60%.

5) Because illumination level is inversely proportional to square of a distance, regulating lamp height will aid in lighting energy saving.

6). Electronic ballasts for discharge lamps cut energy consumption by 20%.

7) The installation of an intelligent lighting controller will aid in the regulation of lighting energy.

8). The use of photo sensor switches for street light control aids in the ~~cons~~ conservation of lighting energy.

Energy conservation in electrical industries

Combined and write the answers for small scale industries and energy conservation measures in lighting systems (above two questions answers).

Energy conservation in

i) Space heating

1). Limiting heat losses from the building
2). Avoid any improper use of heating
3). Optimize the output of heat generators
4). Use heat pumps
5) Use solar heating
6). Optimize heating circuits
7). Optimize heating control.

ii). air- conditioning

1). Improvements in equipment or system operation

2). Minimizing the load on the system.

3). Use a smart thermostat.

Energy efficiency improvement is achieved in energy efficiency motor for the following power loss area i) iron ii) Stator and rotor I^2R. iii) Friction and windage

i). Iron

1). Core loss in the amount of energy required to magnetise the core material and includes losses caused by eddy currents that flow in the core

2). Core losses are reduced by using high permeability electromagnetic steel and prolonging the core to lower magnetic flux densities.

3). Eddy current losses are decreased by using thinner laminations

ii) a) Stator

1). They are also called I^2R losses which are due to resistance of stator.

2). Stator losses can be reduced by changing the design of the stator slot or by reducing insulation thickness to increase the volume of wire in the stator.

b). Rotor I^2R

1). It is also called I^2R losses which are due to the resistance of stator

2). Rotor losses can be reduced by increasing the size of conductive bars and end rings, resulting in a lower resistance, or by decreasing the electrical current.

iii) Friction and windage

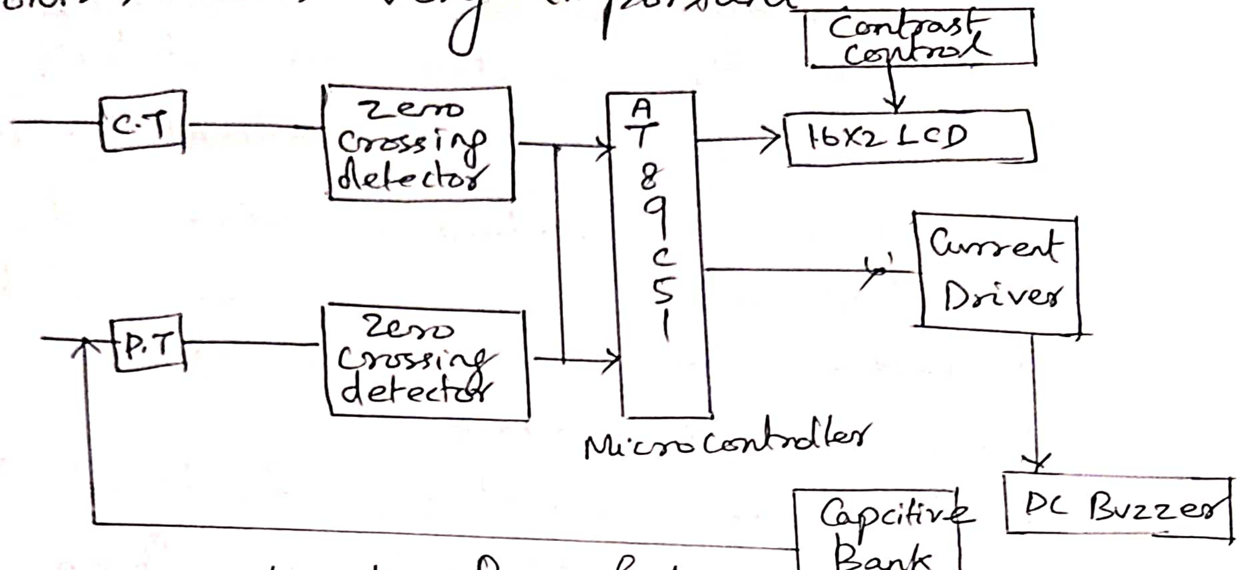
1). They are caused by frictional forces at motor shaft bearings. These losses are usually related to the cooling fan.

2). The use of a low loss fan design decreases air movement losses.

Simulation study of energy conservation using power factor controller

Majority of the loads in the industries are highly inductive in nature such as induction motor, AC/DC drives, welding machines, flourescent lightings, computer etc. Net industrial load is highly inductive causing a very poor power lagging power factor. If this poor power factor is left uncorrected, the industry will require a high maximum demand from Electricity board and also will suffer a penalty for poor power factor.

So the requirement of power factor controller is very important



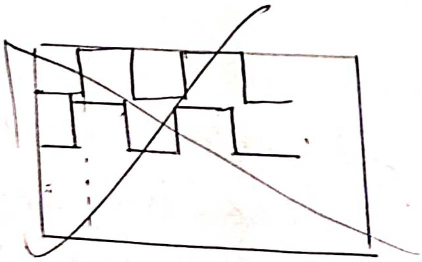
Automative Power factor controller

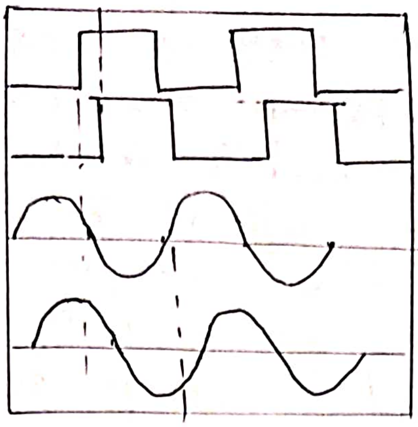
The block diagram of automatic power factor controller is shown in figure. The supplied voltage and current signals, taken through a potential transformer and a current transformer. The two sinusoidal waveforms are being changed to square waves through two zero crossing detectors. These digital square waves are used by microcontroller to calculate phase difference and thus power factor

A capacitive load bank is used which develops an electric load, applied to an electric power source and converts or dissipates the resultant power output of the source.. In this way help to improve powerfactor. The status of APFC system is displayed on LCD such as lagging or leading, calculated powerfactor etc. Micro controller used is AT89C51 which is heart and brain of the entire APFC system. It takes input from user and zero crossings of current, voltage waveforms. It contool the capacitor bank as required to compensate for leading or lagging power factor.

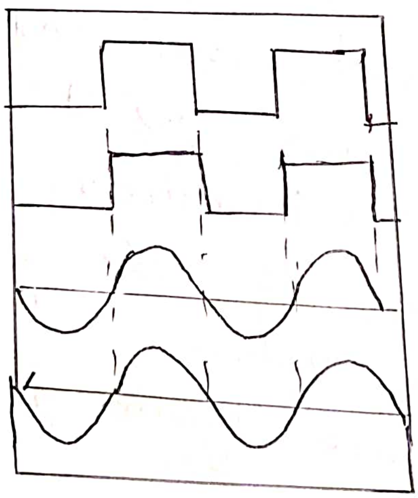
<u>Simulation and observations</u>

The simulation tool used for the analysis of the APFC system is Proteus VSM. It is an interactive circuit simulation tool in the design environment. It is possible to draw a complete circuit for a micro-controller ~~design~~ based system and then test it interactively, all from within the same piece of software. For the educational user and engineering purpose ISIS also used for producing attractive schematics. The following simulation result, it shows input waveform of voltage and current with phase difference. Lower power factor is not





acepted as per standard because poor or low power factors affect efficiencies. Poor power factor is compensated by capacitor bank. After detecting poor power factor APFC system swites one capacitor at a time. If required, next cycle is repeated. This is repeated till the compensation is achieved. The following simulation result shown in figure, shows the improvement of power factor.



So the power factor controller control the power factor and also enery conservation process in done. This has been explained with the help of simulation study.

Two marks

1). Define energy conservation

Energy conservation refers to effort undertaken to limit energy use. This can be acomplished by either utilizing less energy for a steady service or by reducing the amount of services used.

2). What is the aim (or objective) of energy conservation?

Energy conservation aims to minimise demand, discover and employ alternative energy sources, and clean up the harm caused by previous energy operations.

3). What is the effect of load factor on energy conservation?

The load factor results in a decrease or increase in peak demand and the cost of the power plant.

4). Describe the significance of Bureau of Energy Efficiency (BEE)

The Bureau of Energy Efficiency missio is to help in the development of policies and strategies with a focus on self-regulation and market principles, within the general framework of the Energy conservation Act of 2001, with the primary goal of reducing the Indian economy's energy intensity.

5). What do you mean by energy conservation legislation?

1). The Indian government enacted the energy conservation Act 2001, in response to the tremendous potential for energy savings and the advantages of energy efficiency.

2). The act establishes a legal framework, administrative arrangements, and a regulatory mechanism at the federal and state level to launch the country's energy efficiency programme.

6). What is energy conservation planning?

Energy conservation planning is to findout

i) Specifying energy conservation targets and preparing detailed plan for conservation

ii) Identifying the facilities which are energy inefficient

iii) Adoption of energy conservation measures
iv) Evaluation of energy conservation benefits.

7). What is energy conservation act 2001?

The Indian government enacted the energy conservation act in response to the potential and benefits of energy conservation. This legislation provides a legislative structure and organisation to achieve the energy efficiency. It successfully bridges the demand-supply gap, saves energy and decreases environmental emissions

8). What is the objective of energy conservation act 2001?

The objective of energy conservation act is, to promote efficient use of energy and its conservation through certain statutory measures to ~~provide~~ promote conservation of energy and facilitate its efficient use in various sectors of our country.

9). What are the importance of energy conservation?

i). Energy conservation will lower the cost of fossil fuels

ii) Scientific research benefits from energy conservation because ~~B~~ energy savings allows researchers to do more research.

iii) Energy saving would boost the economy

iv) Energy conservation is important for environmental protection.

10). Mention some equipments used for energy conservation.

1). LED's 2). CFL lamps

3). Smart thermostats 4). Solar charger

5). Smart power strips 6). Solar heater.

UNIT – V

DOMESTIC UTILIZATION OF ELECTRICAL ENERGY

House wiring – working principle of air conditioning system, Induction based applications, ON line and OFF line UPS, Batteries – Power supply aspects – non linear and domestic loads – Earthing system for domestic, industrial and Substation

House wiring

House wiring consists of an electrical wiring system that distribute energy to be used in equipment and applications around the house. It also involves the proper installation and operation of electrical outlets, switches, breakers, meter base and different electrical circuits.

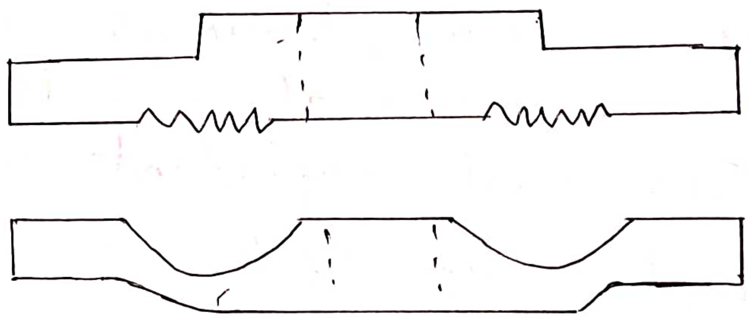
The most important requirement of the electical wiring system is safety. The electrical wiring must be installed correctly and safely in accordance with electrical regulations and standards. Proper material should be used for laying the domestic wiring depending upon the environment, location, safety to personal, to equipments etc

Types of domestic wiring

1). Cleat wiring
2). Wooden casing and caping wiring
3). TRS or Batton wiring
4). Surface conduit wiring
5). Concealed conduit wiring

Cleat wiring

In this system of wiring cables are gripped and supported between cleat made in two halves, of porcelain. These cleats made to accomodate, the lower part is grooved and the upper part is put over it. the cable and the cable is put between the cleats, After the cable is put-between the cleats, these are then screwed on wooden plugs also known as gutties.



Cleats for two wires are shown in figure. The cables normally used in cleat wiring are VIR (Vulcanised India Rubber) cable, PVC cables etc. The gutties should first be fixed into the wall at regular intervals of about 50 cm. The screws are used, size of 38 mm length.

Advantages

1). The installation and dismantling is simple and fast, hence it is very useful for temporary wiring.

2). The cable can be inspected easily and if there is any problem with the wiring the same can be rectified without much problem.

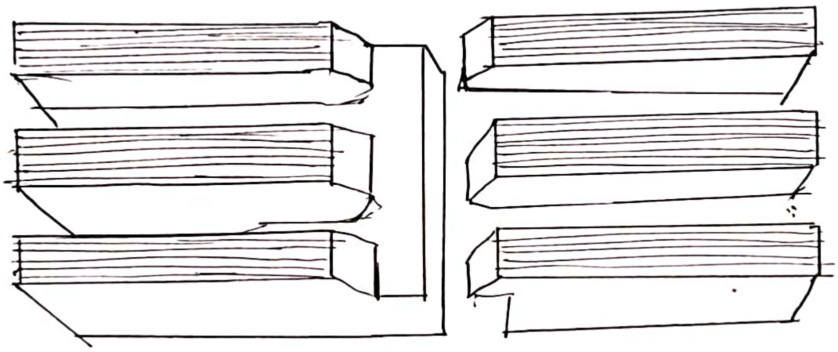
Disadvantages

1). The appearance of the wiring is not good

2). It cannot be used in damp places.

3). As the wiring is exposed to atmosphere, its life span is short

2). Wooden/pvc casing and Capping wiring



This method of wiring is one of the old method. The casing and caping form two parts of wooden or PVC, the casing and capping have grooves. The cable is placed in the grooves of the casing and this is then covered by capping as shown in figure. The capping is fitted to the casing with the help of screws 12.7 mm length.

Advantages

1). Short circuit of wire is avoided as phase and neutral are placed in different grooves.

2). physical inspection of wiring makes it simple to carryout any repair.

3). PVC casing caping giving better look and is economical.

Disadvantages

1). In case of short circuit, there is risk of fire.

2). Normally not recommended for damp places.

3). Toughned Rubber sheet or Batton wiring

In this case the cables are carried on seasoned teak wood perfectly straight and well varnished teak wood bottom of thickness not less than 1 cm. The cables are fixed on the bottom by means of tinned brass or aluminium link clips already fixed on the bottom with small nails before laying cables.

The battons are fixed to the walls by means of gutties with wooden screws. The screws are fixed on the batton at an interval about 75 cms.

Advantages

1). Easy to detect fault if any and has good appearance.

2). Relatively good life span.

Disadvantages

1). Not suitable if exposed to sun and rain or places where dampness exists.

2). Risk of fire high

4). Conduit wiring

There are three types of conduit wiring

i) Concealed conduit wiring

ii) Surface conduit wiring

iii) Flexible conduit wiring.

i). Conceaded conduit wiring

Here the conduits are embedded along the wall in plaster at the time of construction. The conduit should be electrically and mechanically continuous and connected to earth at some suitable places using earth wire. This method is preferred for domestic wiring because it maintains the beauty of the house and no projected pipes are visible.

ii). Surface conduit wiring

The conduit is spaced from the wall by means of small wooden spaces below the conduits along its length at regular intervals. This system is commonly used in industrial wiring.

iii) Flexible conduit wiring

This is not a general method of wiring. If is used for connecting rigid conduit (surface conduit) with machine terminal box in case of motor wiring and energy meter with main switch in case of industrial and domestic wiring.

Distribution board

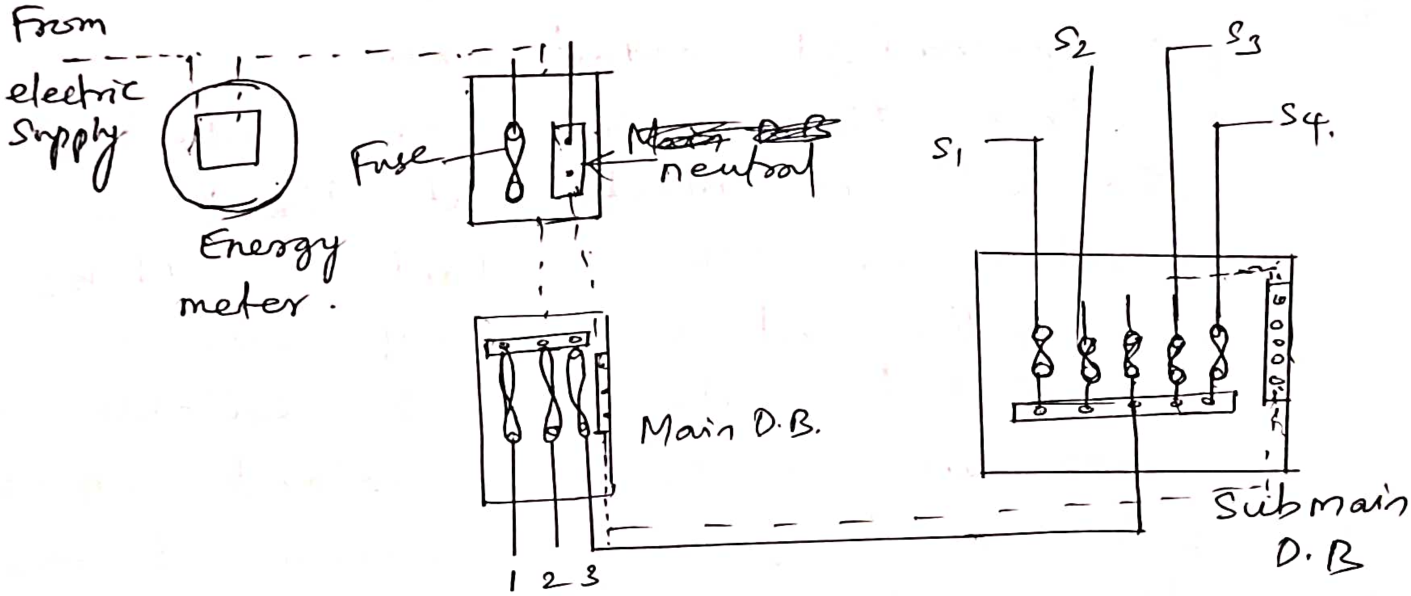


Figure shows a distribution board located in covered Verandah in a house or in the room... Select the location of the meter board as the meter reader shall be visiting the house regularly. The cable from the electric supply is connected to the energy meter first before taking it to any other connection.

The phase wire is connected to a metal bar or bus bar of the main distribution board through a fuse, a neutral link of the DPIC switch is connected to neutral link of the main distribution board. From here the neutral wire is distributed one each with various phase wires to form a complete sub circuit.

Cables

Various cables used in domestic wiring are given here

Vulcanized Rubber

Rubber in its natural form is highly insulating but it absorbs moisture readilly and gets oxidized. When it is mixed with sulpher along with other, it changes into vulcanized rubber which does not absorb moisture. The electrical properties expected of rubber insulation are high breakdown strength and high insulation resistance.

2). PVC (Poly Vinyl Chloride)

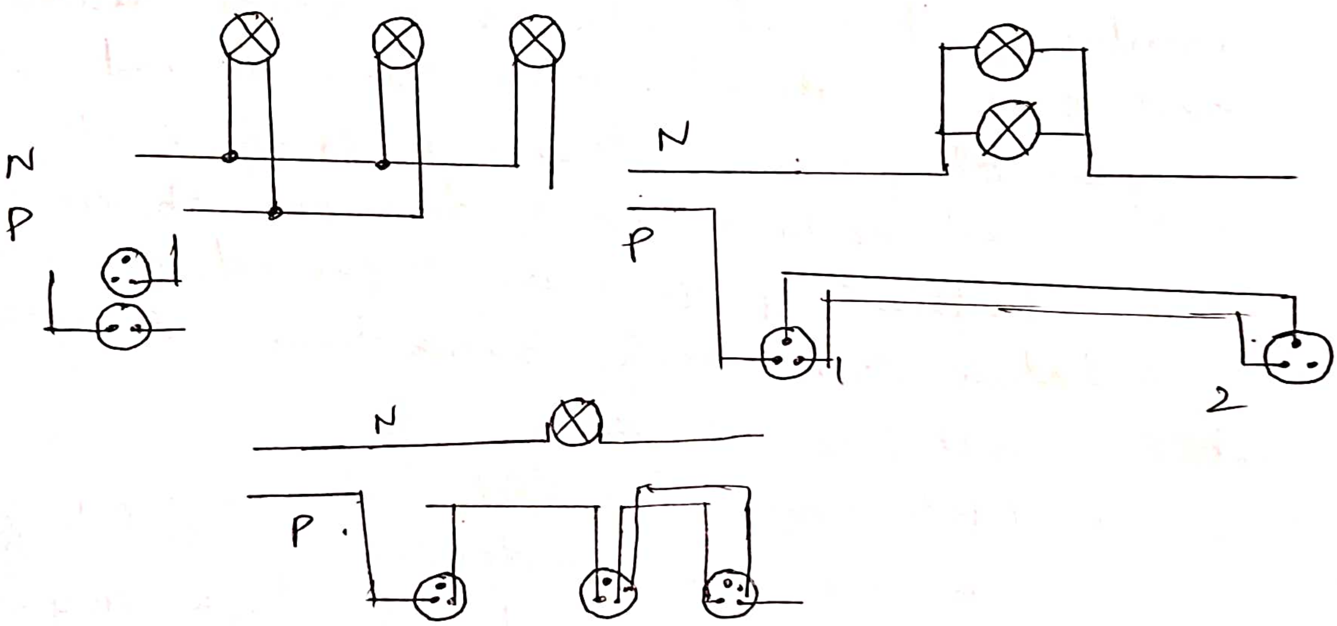
These are thermoplastic insulating materials and not used for high temperature as it gets softned and flows down to heat. The PVC insulated cables are lessen in diameter as compared to TRS wire. These are used upto 1.1 kV voltage especially in concealed wiring system.

3). TRS or CTS cables

Tough Rubber Sheathed (TRS) or Cab Type Sheathed (CTS) cables. This cable is used where humidity is high and it does not deteriorate even during long duration of exposure to moisture.

Lighting control circuits

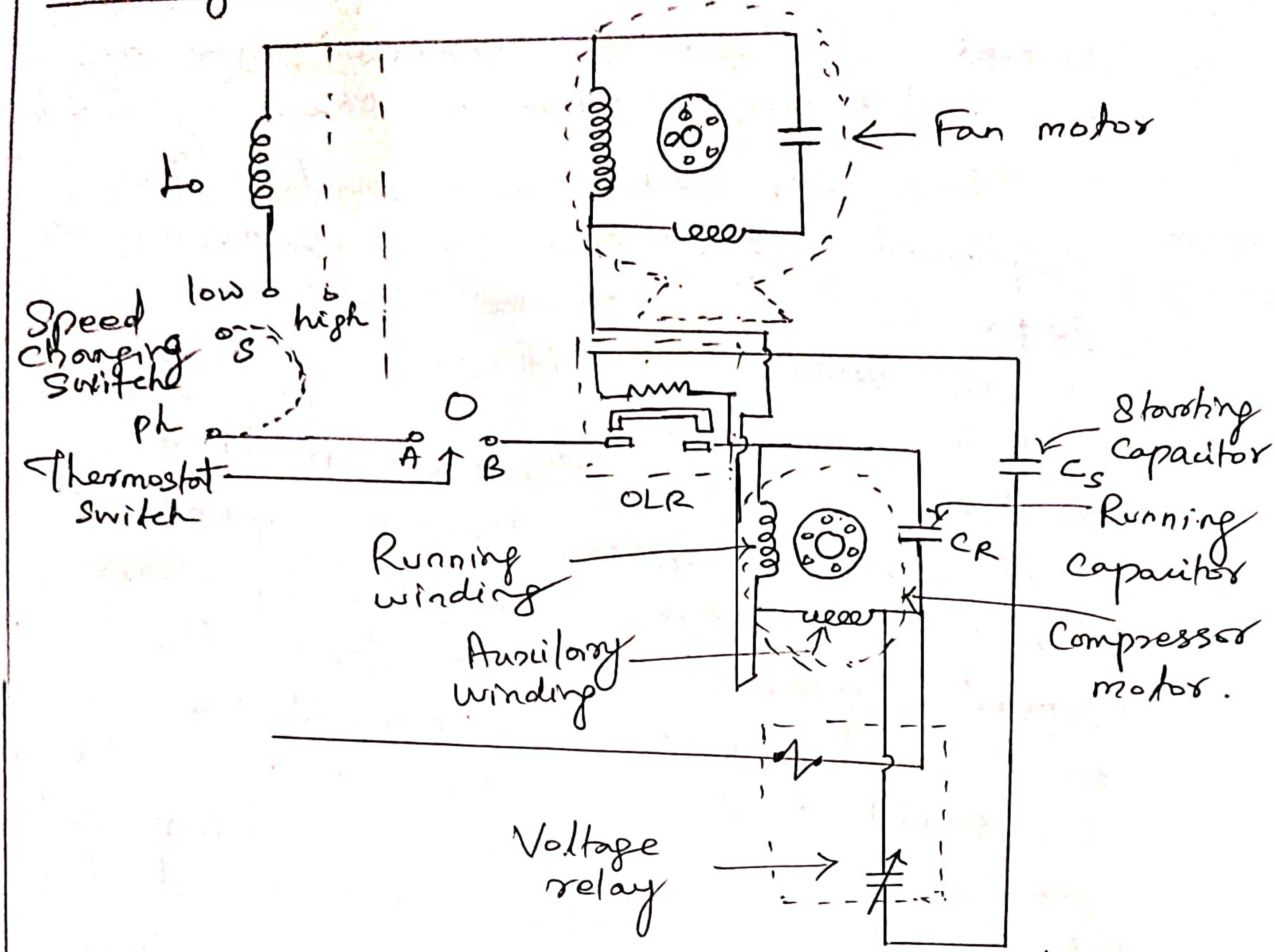
Various lighting control circuits have been developed for maximum convenience and economical use of electric lighting. Circuit diagrams for various switching circuits are shown below



Air conditioning

The process by which the temperature, humidity, purity and circulation of air is controlled in an enclosed area is know as air conditioning

Working principle



Air conditioner is provided for the treatment of air in an enclosed space. The working principle of an air conditioner is same as to a water cooler. It has two fans. One is for cooling of condenser and the other fan is blower, which circulates cooled air into the room.

For small air conditioners, two fans are arranged on both ends of the same shaft, but for the large air conditioners, two fans are operated by two different motors. The electric circuit for an air conditioning system is shown in figure.

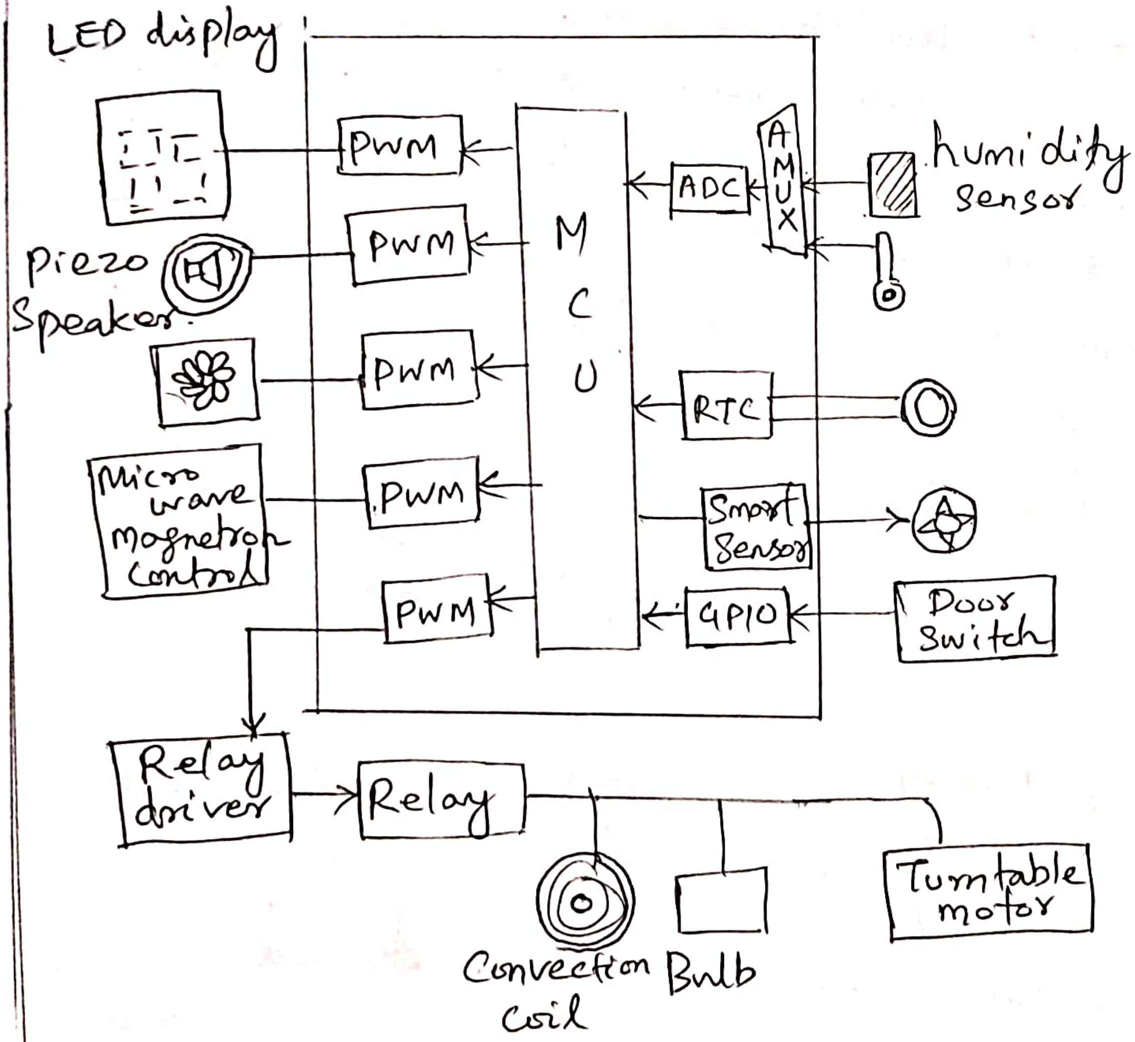
The air conditioning system that is employed with two fans is driven by two seperate ~~split~~ single phase split ring induction motors. When the thermostat switch is open and the fan motor is directly connected across the supply through point ~~S~~ and fan motor starts working. Here the speed of the fan motor is can be controlled by changing the speed changer switch position. The speed of the fan motor is reduced by closing the switch 'S' to low position by adding machine inductance 'Lo' in series with the motor circuit. and increased by closing the switch 'S' to high position without connecting any inductance in series with the circuit.

When the thermostat switch closes, the compressor motor starts running with the help of both auxilary and main windings. The compressor motor is a start capacitor that is run by a single phase induction motor to develop 80-85% of synchronous speed, voltage relay automatically disconnects the auxilary winding

Now the motor is able to run continuously with running or main winding alone. Over load Release (OLR) function is to protect the compressor motor from overloads. In case if there is any overload occuring on the motor, overload release coil energize, this automatically disconnects the motor from the supply and causes the safe operation of compressor motor.

Induction based Appliances

1). Induction cooking stove

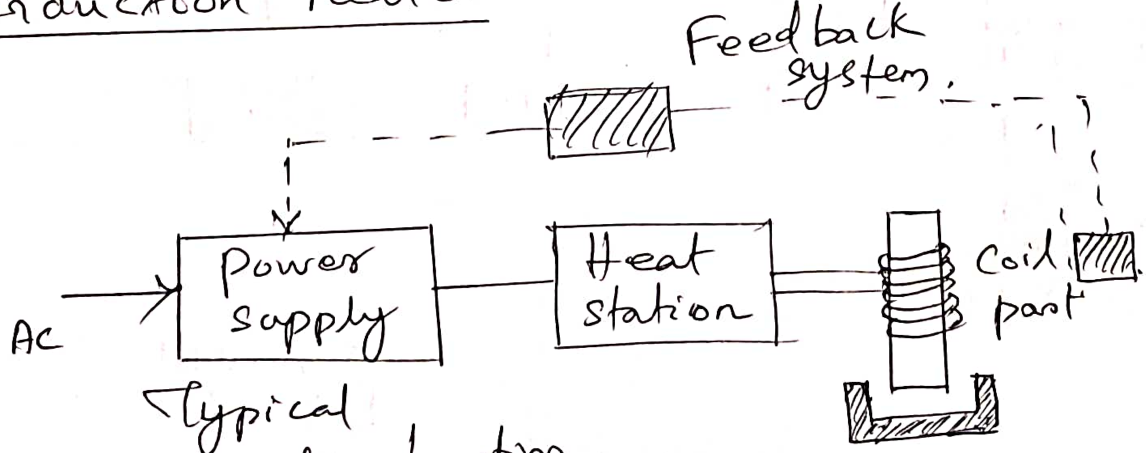


Induction cooking uses electric currents to directly heat pots and pans through magnetic induction. Instead of using thermal conduction, induction heats the cooking vessel itself almost instantly.

An electric current is passed through a coiled copper wire underneath the cooking surface, which creates a magnetic current throughout the cooking pan to produce heat.

Induction cooking is more efficient, safe and provide friendly user interfaces. Resonant switching are typically used for the power converter in these appliances to achieve lower levels of electromagnetic interferences (EMI). The arrangement and various control circuits for Induction cooking stove is shown in figure.

Induction heater.



Typical induction heating setup.

The setup used for induction heating is shown in figure. It consists of an RF power supply to provide the alternating current to the circuit. A copper coil is used as inductor and current is applied to it. The material to be heated is placed inside the copper coil.

Control of heating temperature is done by altering the strength of applied current. As the eddy current produced inside the material flows opposite to the electrical resistivity of the material, precise and localized heating is observed in this process.

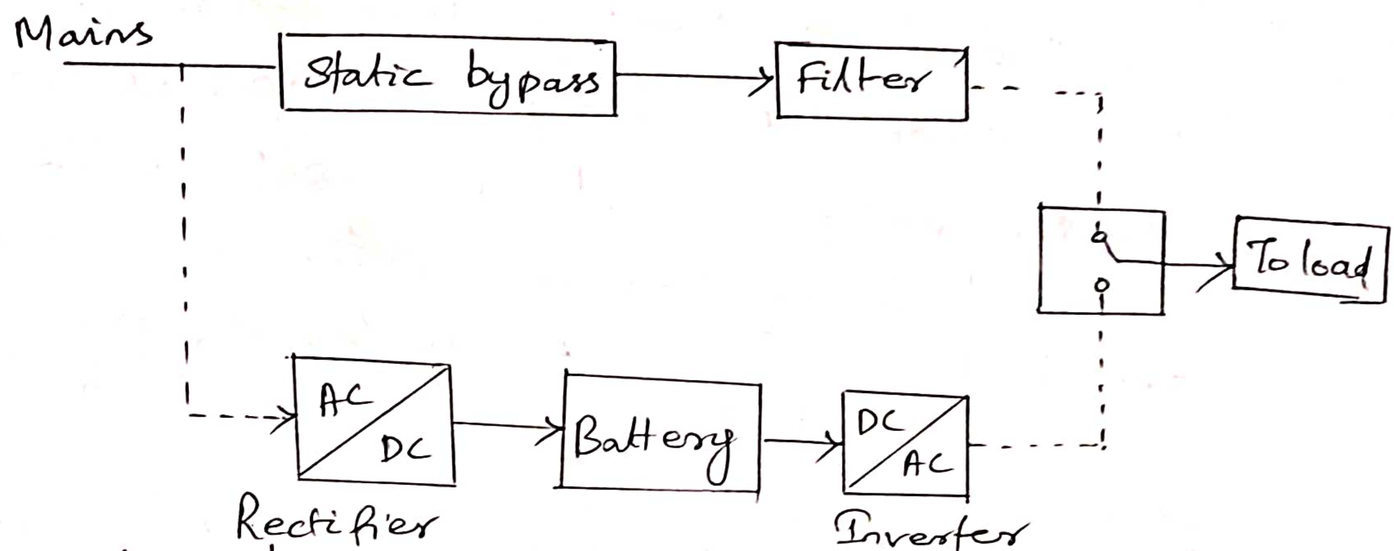
Besides eddy current, heat is also generated due to hysteresis in magnetic parts. The electrical resistance offered by a magnetic material, towards the changing magnetic field within the inductor, cause internal friction. This internal friction creates heat.

As the induction heating process is a non contact heating process, the material to be heated can be present away from the power supply or submerged in a liquid or in any other gaseous environment or in a vacuum. This type of heating doesn't require any combustion gases.

Uninterruptible Power Supply (UPS).

An uniterrruptible power supply is defined as a piece of electrical equipment which can be used as an imediate power source to the connected load when there is any failure in the main input source.

OFF line UPS

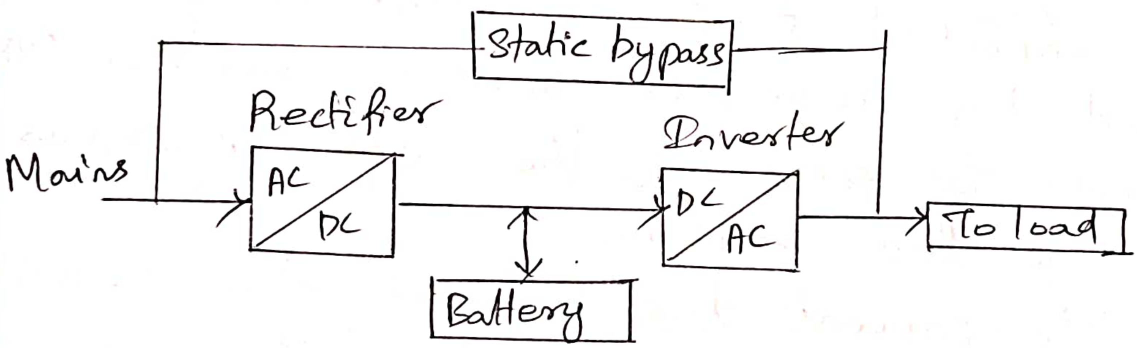


The block diagram off-line UPS is shown in figure. This is also called as stand by UPS system. Here the primary source is the filtered AC mains. When the power breakage occurs, the transfer switch will select the backup source.

This stand by system will start working when there is any failure in mains. In this system, the AC voltage is first rectified and stored in the storage battery connected to the rectifier.

When power breakage occurs, this DC voltage (stored in battery) is converted to AC voltage by inverter and is transferred to the load connected to it. This is the least expensive UPS system and it provides surge protection in adittion to backup. The transfer time can be about 25 milliseconds which can be related to the time taken by the UPS system to detect the utility voltage that is lost.

ON Line UPS



The block diagram of ON line UPS is shown in figure. In this type of UPS double conversion method is used. Here first the AC input is converted into DC by rectifying process for storing it in the rechargeable battery. This DC is converted into AC by the process of inversion and given to the load or equipment which it is connected.

This type of UPS is used where electrical isolation is mandatory. This system is a bit more costly due to the design of constantly running converters and cooling systems.

Here the rectifier which is powered with the normal AC current is directly driving the inverter, hence it is also known as double conversion UPS.

When there is any power failure, the rectifier have no role in the circuit and the steady power stored in the batteries which is connected to the inverter is given to the load by means of transfer switch. Once the power is restored, the rectifier begins to charge the batteries.

To prevent the batteries from overheating due to high power rectifier, the charging current is limited. During a main power breakdown this UPS system operates with zero transfer time. The reason is that the backup source acts as a primary source and not the main AC input. But the presence of inrush current and large load step current can result in a transfer time of about 4-6 milliseconds in this system.

Applications

- Data centers
- Industries
- Tele communications
- Hospitals
- Banks and insurance

Advantages

(i). No delay between switching from the power source to the UPS

ii) Can provide better support to critical instruments compared to generators

iii) Consumers can choose the type and size of UPS.

iv) UPS's are silent, they dont make any noise

v) Maintenance of UPS systems is cheaper compared to generators

Disadvantages

i) They have inability to run heavy appliances, because they are run off batteries.

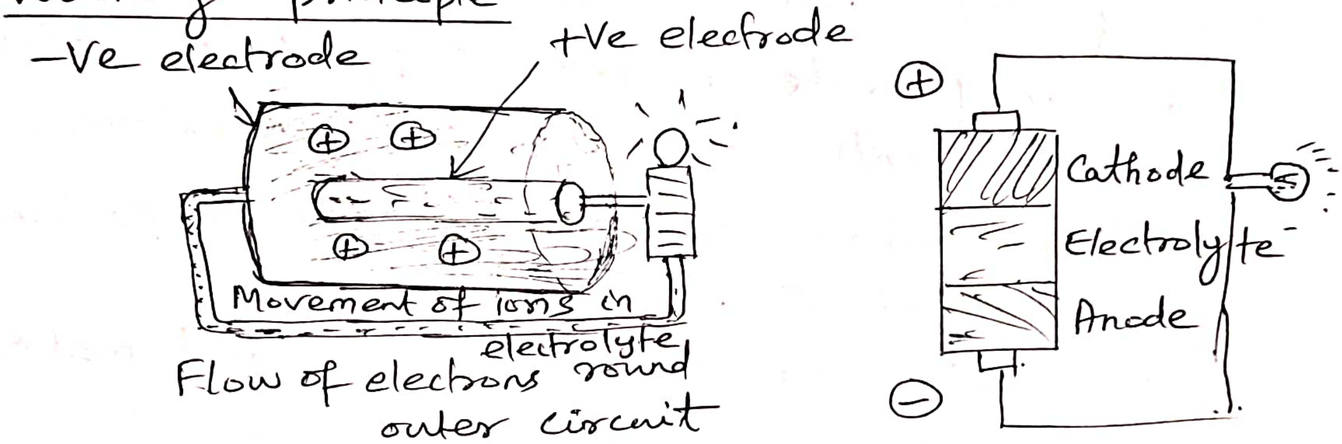
ii) UPS's may need professional installations

iii) If substandard batteries are used, users may endup replacing the batteries often.

Batteries

A battery is a device consisting of one or more electrical cells that convert chemical energy into electrical energy. Every battery is basically a galvanic cell where redox reactions take place between two electrodes which acts as the source of chemical energy.

Working principle



Basic principle of battery

A battery works on the oxidation and reduction reaction of an electrolyte with metals. When two dissimilar metallic substances, called electrode, are placed in a diluted electrolyte, oxidation and reduction reaction take place in electrodes respectively, depending upon the electron affinity of the metal of electrodes. As a result of oxidation reaction, one electrode gets negatively charged called cathode and due to the reduction reaction, another electrode gets positively charged called anode.

The cathode forms the negative terminal whereas anode forms the positive terminal of a battery.

If two kinds of metals are immersed in the same electrolyte solution, one of them will gain electrons and other will release electrons. Which metal will gain electrons and which will lose electrons, depend upon the electron affinity of these metals. The metal with low electron affinity will gain electrons from the negative ions of the electrolyte solution

The metal with high electron affinity will release electrons and these electrons come out into the electrolyte sollution and are added to the positive ions of the sollution. In this way one of these metals gains electrons and another one losses electrons. As a result, there will be a difference in electron concentration between these two metals. This is the general working principle of battery.

Types of battery

1). Primary cell

These batteries where the redox reactions proceed in only one direction. A primary battery cannot be used once the chemicals inside it are exhausted.

Ex: dry cell – the household battery that commonly used to power TV, remotes, clocks and other devices

2). Secondary cell

These are the batteries that can be recharged after use by passing current through the electrodes in the opposite direction.

Ex: lead storage battery

3). House hold batteries

These are used in a wide range of house hold appliances. These are further classified into

i). Rechargeable batteries

Ex: Cadmium batteries, Lithium-Ion

ii) Non-rechargeable batteries

Example: Silver Oxide, Alkaline & carbon Zinc

4). Industrial batteries

These batteries are built to serve heavy-duty requirements. Some of their applications include rail road, backup power

and more for big Companies.
Examples : i) Nickel Iron. ii) Wet Nickel Cadmium (NiCd)

5). <u>Vehicle Batteries</u>

These are more user friendly and a less complicated version of the industrial batteries. They are specially designed to power cars, motorcycles, boats and other vehicles. Example : Lead acid battery.

<u>Power Quality Aspects</u>

The main concern of consumers of electricity is the reliability of supply. Reliability is the continuity of electric supply. ~~And also~~ Power quality also very important.

Power quality ~~is~~ is any abnormal behaviour on a power system arising in the form of voltage and or current. It is defined as any deviation of the voltage or current waveform its normal sinusoidal wave shape. These disturbances under voltage, interruption, swell, over voltages, transients, harmonics, voltage flickers and any other distortions to the sinusoidal wave form occurence of one or ~~at~~ more of such disturbance is called a power quality event.

Power quality have a large decremental effect on industrial processes and the commercial sector. The important power quality considerations to be accounted for to the industrial end user centre.. Solutions to power quality problems must be implemented by industrial end users.

Domestic customers not to be so affected by power quality problems in that equipment for home purposes.

Power quality issues

1). Power frequency disturbances

Power frequency disturbances are low frequency phenomena that result in voltage sags or swells.

2). Power System transient

Power system transients are a fast short duration event that produces distortions such as notching ringing and impulse.

3). Grounding and bonding

The fundamental objective of grounding is safety and nothing that is done in an electrical system should compromise the safety of people

4). Electromagnetic Interference (EMI)

EMI refers to the interaction between electric and magnetic fields and sensitive electronic circuits and devices. EMI is predominantly a high frequency phenomenon.

5). Power system Harmonics

Power system harmonics are low frequency phenomena characterized by wave form distortion, which introduces harmonics frequency components. Voltage and current harmonics are undisirable effects on power system operation.

6). Electrostatic discharge

Electrostatic discharge (ESD) is very familiar and unpleasant occurence. At high levels, ESD is harmful to electronic equipment, causing malfunction and damage.

7). Power factor

Power factor is an economic issues in the operation of a power system. As utilities are increasingly faced with power demands that exceeds generation capability, the penalty for low powerfactor is expected to increase. In some cases, low powerfactor is responsible for equipment damage due to component overload.

Non-linear and Domestic loads

Non linear load

A load is ~~consi~~ considered non-linear if its impedance changes with the applied voltage. The changing impedance means that the current drawn by the non-linear load will not be sinusoidal even when it is connected to a sinusoidal voltage.

Non-linear loads are in heavy industrial applications such as arc furnaces, large variable speed drives, rectifiers. SMPS, computers, printers, chargers, telecom systems also non linear loads present.

The SMPS is a excellent power supply, but it is also a highly non linear load. A non linear load in a power system is characterized by the introduction of a switching action and consequently current interruptions. This behaviour provides current with different components that are multiples of the fundamental frequency of the system. These components are called harmonics.

The amplitude and phase angle of harmonic is dependent on the circuit and on the load it drives. For a fundamental power frequency of 60 Hz, the second harmonic is 120Hz, the 3rd harmonic is 180 Hz.

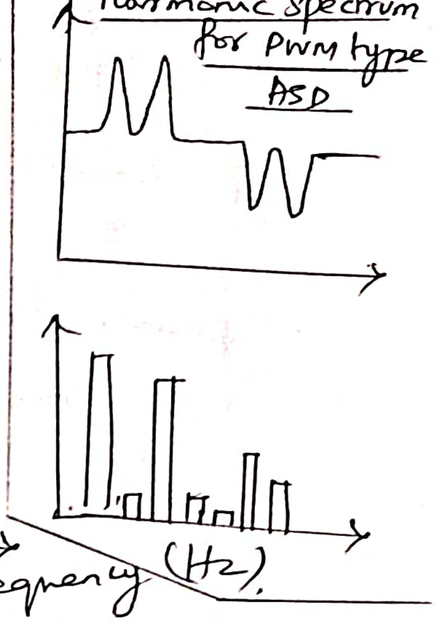
Current distortions can produce voltage distortions. When currents with harmonics flow through electrical generation systems and transmission lines, additional distortions takes place because of the impedance of the electrical network.

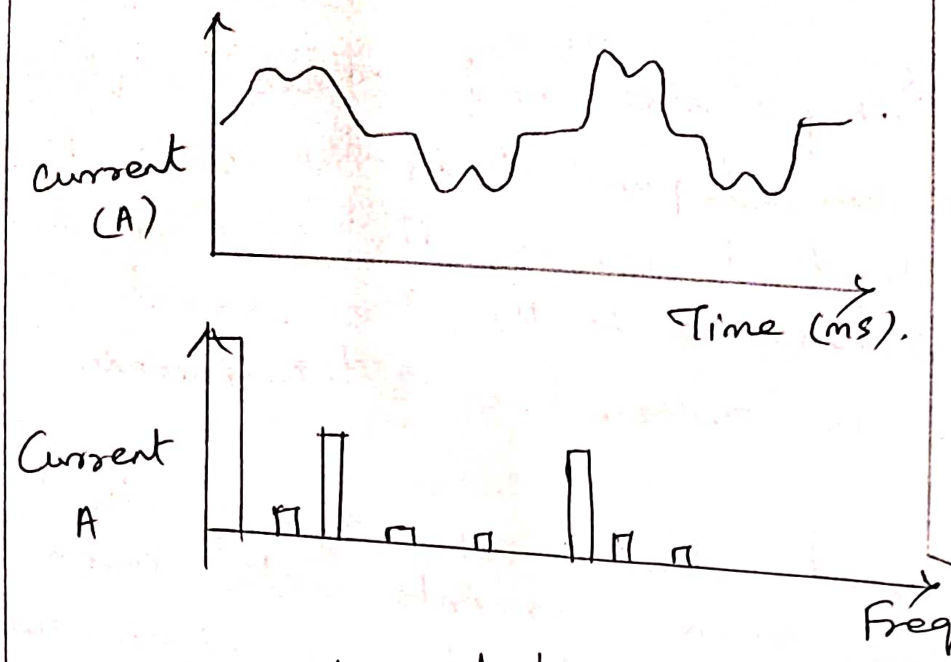
The more nonlinear loads connected, the higher the overall sum of harmonics though the sum of the individual magnitudes. Harmonics can damage components like fuses and circuit breakers and can cause utility meters to record wrong measurements.

The current and harmonic spectrum of CSI type ASD and PWM type ASD (Adjustable Speed Drive) are shown below.

The sine wave distortion can understand from the figure

Current and harmonic spectrum for PWM type ASD





Current and harmonic spectrum of CSI type ASD

Domestic Load / Residential load

The domestic load is defined as the total ensumed by the electrical appliances in the household work. It depends on the living standard, weather and type of residence. The domestic loads mainly consist of lights, fan, refrigerator, air conditioners, mixer, grinder, heater, ovens, small pumping, motor etc.

The domestic load consume very little power and also independent from frequency. This load largely consists of lighting, cooling or heating. Most of the domestic loads are connected for only some hours during a day. For example lighting load is connected for few hours during night time.

Earthing

By earthing of electrical installations is meant the direct connection of all the metal non current carrying parts of electrical equipments. e.g. metallic framework, body of electric machines, main switch, metallic covering of cables and conduits, distribution board, earth terminal of sockets etc to earth plate.

The earth plate is buried in the ground which has good electrical connection to the surrounding earth.

Domestic earthing

Domesting earthing is classified into two types

1). System earthing

This type of earthing which is associated with current carrying conductors. Overflow of currents during the process of its transmission. This type of earthing is put to use in stations and substations of electrical supply.

2). Equipment earthing

This is the prime type of earthing for homes and other buildings. It deals with the safeguarding of non current carrying apparatus and metalic conductors. This type of earthing serves the dual function of protecting the user of the appliance against shocks.

Methods of earthing

There are several common methods employed for earthing of appliances and each of them is used according to the site of the building.

1). Plate earthing

A 2.5 metre deep pit is dug into the ground and a Galvanished Iron (GI) plate is placed inside along with charcoal and sand for the purpose of maintain low resistance around the plate.

An earth wire, which is of GI or tinned copper, is bolted to the plate before burying it by means of nuts, bolts and washers.

The wire is made to pass through a GI pipe through which some water is poured to increase conductivity. The earth wire is connected to the earth point of the socket and is finally covered.

2). Pipe earthing

A 2.5 metre long pipe measuring about 35–75 mm in diameter is burried in the dig out pit along with sand and charcoal. The pipe is provided with several perforations to maintain dampness around and hence conductivity

The earth wire is tied and clamped near the summit. Water may be poured into it during summers. The earth wire is safer against damage in such a setup.

3). Rod earthing

This method employs hammering of zinc and copper rods of about 1–5 meters length and 12-20 mm diameter into the general mass of the earth.

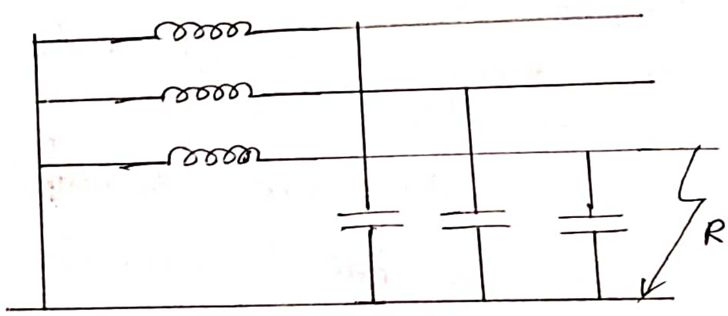
Successive rods are screwed together and this chain is ~~tri~~ied making as long as possible for lowered resistance by the surrounding soil.

The earth wire is tied and clamped near the summit. This is very economical and quick procedure for earthing.

Industrial Earthing

This system earthing, the connection between the transformer neutral points and earth, is of high importance to the behaviour of a power system during an Unsymmetrical fault. The earthing design is considered the single most important parameter to determine the earth fault behaviour in a power system. Two important functions of neutral earthing are to detect earth faults and to control the fault current.

1). Solidly earthed systems.



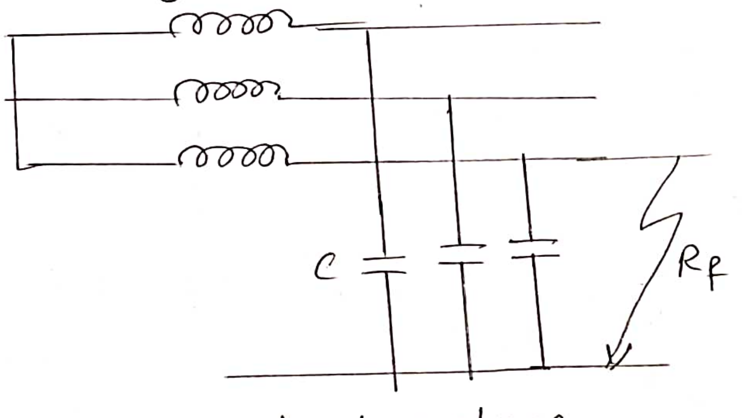
In solidly earthed system a number of the transformer neutrals are directly earthed .. An earth fault in a system with a solidly earthed neutral is shown in figure.

The single-phase earth fault current in a solidly earth system may exceed the three phase fault current. One way to reduce the earth fault current is to leave some of the transformer neutrals unearthed.

2). Isolated neutral systems

A system ~~with~~ where all transformer neutrals are unearthed is called an isolated neutral system. The only intentional connection between an unearthed neutral and earth via high impedance equipment for protection or measurement purpose such as surge arresters or voltage transformers.

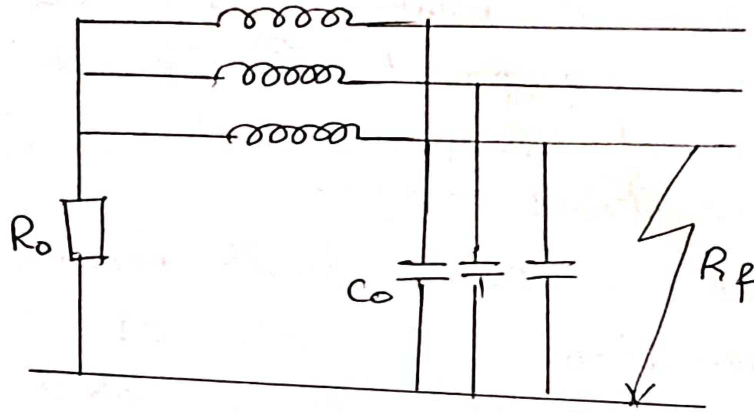
When an earth fault occurs in the system, the capacitance to earth of the faulty phase is bypassed. Figure shows an earth fault in a system with unearthed neutral.



3). Resistance earthed systems

To improve the earth fault detection in a power system a resistance can be connected between a transformer neutral point and the station earthing system. A system where atleast one of the neutral point is connected to earth via a resistor is called a resistance earthed system.

The purpose of the neutral point resistor is to increase the resistive part of the earth fault current and hence improve the earth fault detection. Figure shows an earth fault in a system with a resistance earthed neutral.



4). <u>Resonant earthed system</u>

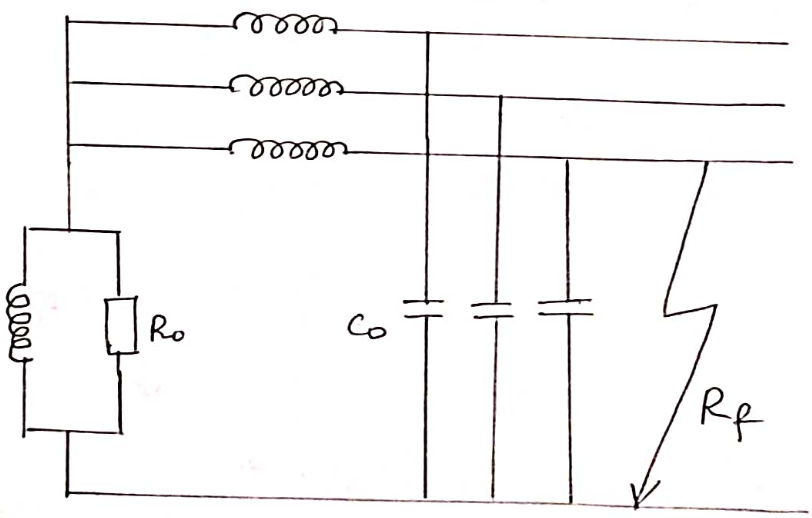


Figure shows an earth fault in a system with a resonance earthed neutral.

To limit the reactive part of the earth fault current in a power system a neutral point reactor can be connected between the transformer neutral and the station earthing system. A system in which at least one of the neutrals is connected to earth via an inductive reactance, a Peterson coil, and the current generated by the reactance during an earth fault approximately compensates the capacitive component of the single phase earth fault current, is called a resonant earthed system.

Substation earthing

Earthing in a substation is very important.

The main function (or need) of substation earthing are

- Provide the neutrals of generators, transformers, capacitors and reactors a connection to earth.
- Offer a low impedance path to the earth for the currents coming from ground faults, lightning rods, surge arrestors, gaps and related devices.
- Limit the potential differences that appear between the substation metallic objects or structures, and the ground potential rise, due to the flow of ground currents.
- Improve the operation of the protective relay scheme to clear ground faults.

- Increase the reliablity and availability of the electrical system.
- Allow the grounding of de-energized equipment during maintenance.

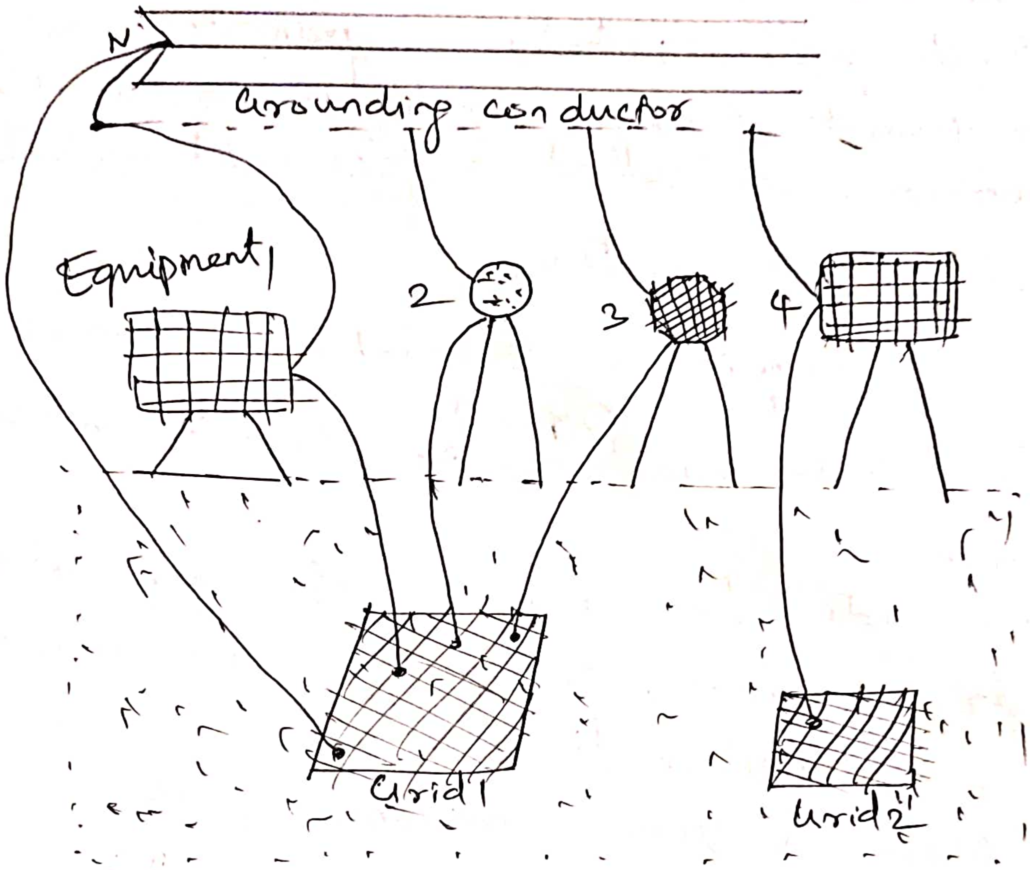


Figure shows a typical grounding network, in the illustration, each piece of equipment has two links to the earth and the grounding conductor. The two links provide dependable circuits for the return of ground fault current. The equipment 4, located at another substation, has a seperate connection to the earth. By using the grounding conductor, the ground connections of the two substations work in parallel, this is beneficial as it reduces the return of current through the ground.

Without the grounding conductor, all ground fault current from equipment 4 will return through earth. The connections to the earth in both substations should have low impedance, so that the ground fault current magnitude will be large enough to activate the over current protection system, clearing the fault.

Equipment frames and steel structures may be used as a path to earth if their conductivity, including joints is equivalent to the required conductor. Examples are the connection of surge arresters to the transformer tank and the overhead ground wires and lighting masts attached to the substation steel structure.

Two marks

1). What is the need for earthing?

i). Earthing protects the personal from the short circuit current

ii) The earthing provides the easiest path to flow of short circuit current even after the failure of the insulation

iii) The earthing protects the apparatus and personel from the high voltage surges and lightning discharges.

2). Which type of battery is used in UPS? Why?

Lead - Acid batteries for reliability when used in an UPS system. They provide most economical.

3). What are the different types of domestic wiring?

1). Cleat wiring

2). Wooden casing and capping wiring

3). TRS or Batton wiring

4). Surface conduit wiring

5). Concealed conduit wiring.

4). What are the main requirements of the insulating materials used for cable?

i). High insulation resistance
ii) High dielectric strength
iii) Good mechanical properties
iv) It should not be affected by chemicals around it

5). What are the important factors for air-conditioning?

i). Temperature control
ii) Humidity control
iii) Humidification
iv) Dehumidification
v). Air movement and circulation

6). What are the advantages of cooking with induction?

i) Boil 50% faster
ii) Precise temperature control
iii) Easy to clean surface
iv) Auto sizing burners

7). Mention the factors to be considered while designing induction heating system.

i). The heat loss due to conduction, convection and radiation should be taken into account for deciding the power supply capacity

ii). Materials for higher resistivity are heated quickly.

iii) While applied to magnetic materials, heat is generated both by eddy current and hysteresis effect.

8). What is offline UPS?

The AC voltage is first rectified and stored in the storage battery connected to the rectifier. When the power breakage occurs, the transfer switch will select the backup source. The standby system will start working only when there is any power failure.

9). What is ~~off~~ on line UPS?

The on line UPS, consisting a rectifier, battery and inverter, is directly connected to both AC mains and the load. The rectifier circuit converts the AC power into DC power.

10). What is the difference between on line UPS and OFF line UPS?

1) The main difference between on line UPS and off line UPS are, On line UPS supplies AC power through a rectifier and inverter circuit even when AC main power is available, whereas off line UPS directly supplies AC mains power to the load circuit when the power supply is available

2) Inverter in on line UPS is always ON, while the inverter in UPS is only active during power outages.

11). Define battery.

A battery is a device consisting of one or more electrical cells that convert chemical energy into electrical energy.

12). Mention the rechargeable batteries
i). Lead acid batteries
ii) Ni-cd batteries (Nickel Cadmium)
iii) Nickel Metal Hybrid (Ni-MH)
iv) Lithium ion batteries
v). Lithium ion polymer

13). What are the power quality issues?
i). Power quality disturbances ii) Power system transient iii) Grounding and bonding iv) EMI v). Power system harmonics vi) ESD vii) Power factor

14). What are the examples of nonlinear loads? (where switching devices i.e diode, IGBT, MOSFET, FET etc used)
furnaces, large variable speed drives, SMPS, UPS, Printers, refrigerators, FAX, TV, computers.

15). What are domestic loads?
Lights, fans, heaters, refrigerators, air conditioners etc. Many of these are only connected for a few hours of each day are called as domestic loads.