A Course Material on

EE-8015 ELECTRIC ENERGY GENERATION AND UTILISATION AND CONSERVATION

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ELECTRICAL ENERGY GENERATION AND
UTILISATION AND CONSERVATION

UNIT IV INDUSTRIAL HEATING AND WELDING

AIM

To expose students to the main aspects of generation, utilization and conservation.

OBJECTIVES

To impart knowledge on

i. Generation of electrical power by conventional and non–conventional methods.
ii. Electrical energy conservation, energy auditing and power quality.
iii. Principle and design of illumination systems and methods of heating and welding.
iv. Electric traction systems and their performance.
v. Industrial applications of electric drives.

1. POWER GENERATION

Review of conventional methods – thermal, hydro and nuclear based powergeneration. Non-conventional methods of power generation – fuel cells - tidalwaves – wind – geothermal – solar - bio-mass - municipal waste. Cogeneration.Effect of distributed generation on power system operation.

2. ECONOMIC ASPECTS OF GENERATION

Economic aspects of power generation – load and load duration curves – numberand size of units – cost of electrical energy – tariff. Economics of power factorimprovement – power capacitors – power quality. Importance of electrical energy conservation – methods – energy efficient equipments. Introduction to energy auditing.

3. ILLUMINATION

Importance of lighting – properties of good lighting scheme – laws of illumination –photometry - types of lamps – lighting calculations – basic design of illuminationschemes for residential, commercial, street lighting, and sports ground – energy efficiency lamps.

4. INDUSTRIAL HEATING AND WELDING

Role electric heating for industrial applications – resistance heating – induction heating – dielectric heating - electric arc furnaces.Brief introduction to electric welding – welding generator, welding transformer and the characteristics.

5. ELECTRIC TRACTION

Merits of electric traction – requirements of electric traction system – supply systems – mechanics of train movement – traction motors and control – braking – recent trends in electric traction.

TOTAL: 45 PERIODS

TEXT BOOKS

1. C.L. Wadhwa, ‘Generation, Distribution and Utilization of Electrical Energy’, New Age International Pvt. Ltd, 2003.
2. B.R. Gupta, ‘Generation of Electrical Energy’, Eurasia Publishing House (P) Ltd, **New Delhi, 2003.**

REFERENCES

1. H. Partab, ‘Art and Science of Utilisation of Electrical Energy’, Dhanpat Rai and Co, New Delhi, 2004.
2. E. Openshaw Taylor, ‘Utilization of Electrical Energy in SI Units’, Orient Longman Pvt. Ltd, 2003.
3. J.B. Gupta, ‘Utilization of Electric Power and Electric Traction’, S.K.Kataria and Sons, 2002.

UNIT-1
POWER GENERATION

1.1 Introduction

In this unit a brief idea of a modern power system is outlined. Emphasis is given to create a clear mental picture of a power system to a beginner of the course Electrical Technology. As consumers, we use electricity for various purposes such as:

1. Lighting, heating, cooling and other domestic electrical appliances used in home.
2. Street lighting, flood lighting of sporting arena, office building lighting, powering PCs etc.
3. Irrigating wast agricultural lands using pumps and operating cold storages for various agricultural products.
4. Running motors, furnaces of various kinds, in industries.
5. Running locomotives (electric trains) of railways.

1.1.1 Basic idea of generation

Prior to the discovery of Faraday's Laws of electromagnetic discussion, electrical power was available from batteries with limited voltage and current levels. Although complicated in construction, D.C generators were developed first to generate power in bulk. However, due to limitation of the D.C machine to generate voltage beyond few hundred volts, it was not economical to transmit large amount of power over a long distance. For a given amount of power, the current magnitude (I=P/V), hence section of the copper conductor will be large. Thus generation, transmission and distribution of d.c power were restricted to area of few kilometer radius with no interconnections between generating plants. Therefore, area specific generating stations along with its distribution networks had to be used.

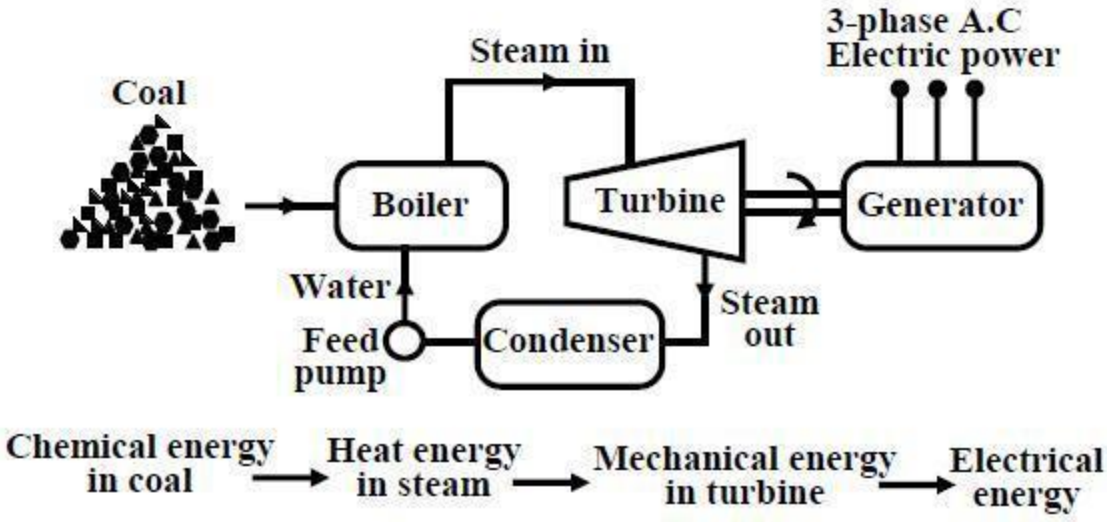
1.2. Review of conventional methods:

1.2 Thermal, hydel & nuclear power stations

In this section we briefly outline the basics of the three most widely found generating stations – thermal, hydel and nuclear plants in our country and elsewhere.

1.2.1 Thermal plant

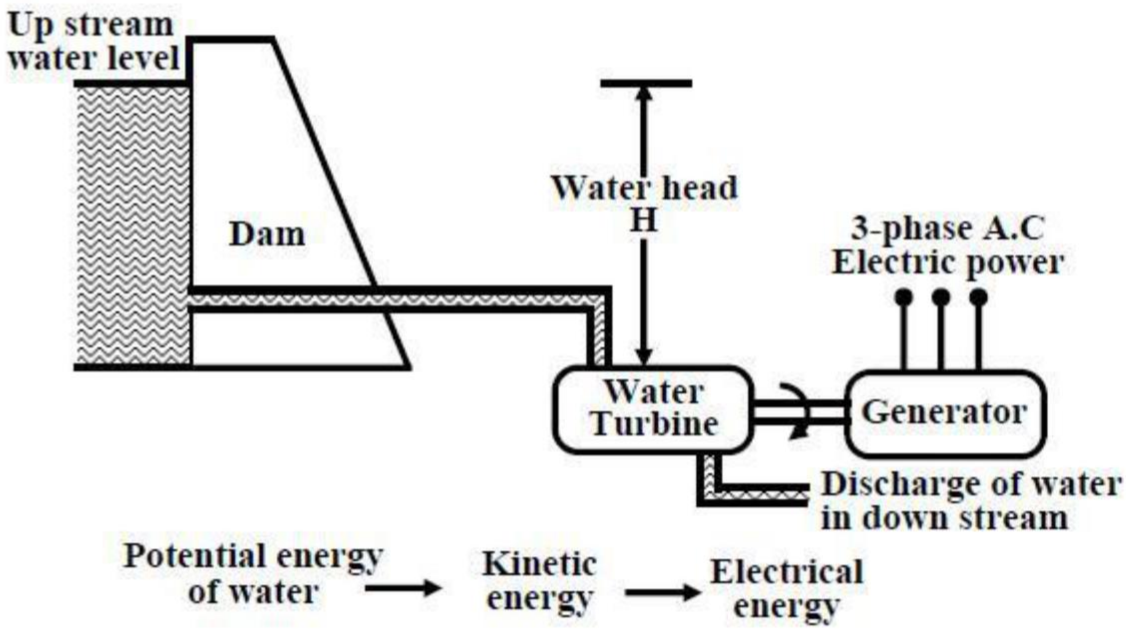
Generate voltage at 50 Hz we have to run the generator at some fixed rpm by some external agency. A turbine is used to rotate the generator. Turbine may be of two types, namely steam turbine and water turbine. In a thermal power station coal is burnt to produce steam which in turn, drives the steam turbine hence the generator (turbo set) the elementary features of a thermal power plant is shown. In a thermal power plant coil is burnt to produce high temperature and high pressure steam in a boiler. The steam is passed through a steam turbine to produce rotational motion. The generator, mechanically coupled to the turbine, thus rotates producing electricity. Chemical energy stored in coal after a couple of transformations produces electrical energy at the generator terminals as depicted in the figure. Thus proximity of a generating station nearer to a coal reserve and water sources will be most economical as the cost of transporting coal gets reduced. In our country coal is available in abundance and naturally thermal power plants are most popular. However, these plants pollute the atmosphere because of burning of coals.



Stringent conditions (such as use of more chimney heights along with the compulsory use of electrostatic precipitator) are put by regulatory authorities to see that the effects of pollution is minimized. A large amount of ash is produced every day in a thermal plant and effective handling of the ash adds to the running cost of the plant. Nonetheless 57% of the generation in our country is from thermal plants. The speed of alternator used in thermal plants is 3000 rpm which means 2-pole alternators are used in such plants.

1.2.2 Hydel plants:

In a hydel power station, water head is used to drive water turbine coupled to the generator. Water head may be available in hilly region naturally in the form of water reservoir (lakes etc.) at the hill tops. The potential energy of water can be used to drive the turbo generator set installed at the base of the hills through piping called penstock Water head may also be created artificially by constructing dams on a suitable river. In contrast to a thermal plant, hydel power plants are eco-friendly, neat and clean as no fuel is to be burnt to produce electricity. While running cost of such plants is low, the initial installation cost is rather high compared to thermal plants due to massive civil construction necessary. Also sites to be selected for such plants depend upon natural availability of water reservoirs at hill tops or availability of suitable rivers for constructing dams. Water turbines generally operate at low rpm, so number of poles of the alternator is high. For example a 20-pole alternator the rpm of the turbine is only 300 rpm.

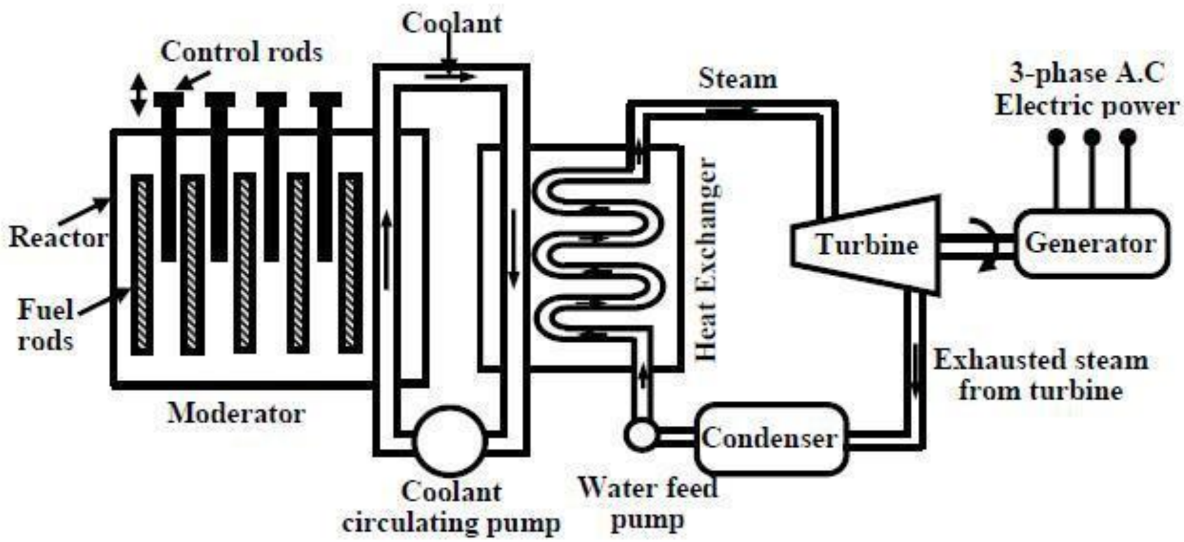


- **Advantages:**
  - ✓ Once the dam is built, the energy is virtual y free.
  - ✓ No waste or pollution produced.
  - ✓ Much more reliable than wind, solar or wave power.
  - ✓ Water can be stored above the dam ready to cope with peaks in demand.
  - ✓ Hydro-electric power stations can increase to ful power very quickly, unlike other power stations.
  - ✓ Electricity can be generated constantly.
- **Disadvantages:**
  - ✓ The dams are very expensive to build.
  - ✓ However, many dams are also used for flood control or irrigation, so building costs can be shared.
  - ✓ Building a large dam will flood a very large area upstream, causing problems for animals that used to live there.
  - ✓ Finding a suitable site can be difficult - the impact on residents and the environment may be unacceptable.
  - ✓ Water quality and quantity downstream can be affected, which can have an impact on plant life.

1.2.3 Nuclear plants:

As coal reserve is not unlimited, there is natural threat to thermal power plants based on coal. It is estimated that within next 30 to 40 years, coal reserve will exhaust if it is consumed at the present rate. Nuclear power plants are thought to be the solution for bulk power generation. At present the installed capacity of nuclear power plant is about 4300 MW and expected to expand further in our country. The present day atomic power plants work on the principle of nuclear fission of U˙ In the natural uranium, U constitutes only 0.72% and remaining parts is constituted by 99.27% of U andonlyabout0.05%ofU.

The concentration of U may be increased to 90% by gas diffusion process to obtain enriched U. When U is bombarded by neutrons a lot of heat energy along with additional neutrons is produced. These new neutrons further bombard producing more heat and more neutrons.



Thus a chain reaction sets up. However this reaction is allowed to take place in a controlled manner inside a closed chamber called nuclear reactor. To ensure sustainable chain reaction, moderator and control rods are used. Moderators such as heavy water (deuterium) or very pure carbon C are used to reduce the speed of neutrons. To control the number neutrons, control rods made of cadmium or boron steel are inserted inside the reactor. The control rods can absorb neutrons. If we want to decrease the number neutrons, the control rods are lowered down further and vice versa. The heat generated inside the reactor is taken out of the chamber with the help of a coolant such as liquid sodium or some gaseous fluids. The coolant gives up the heat to water in heat exchanger to convert it to steam as shown in figure. The steam then drives the turbo set and the exhaust steam from the turbine is cooled and fed back to the heat exchanger with the help of water feed pump. Calculation shows that to produce 1000 MW of electrical power in coal based thermal plant, about 6 × 10Kg of coal is to be burnt daily while for the same amount of power, only about 2.5 Kg of U is to be used per day in a nuclear power stations.

The initial investment required to install a nuclear power station is quite high but running cost is low. Although, nuclear plants produce electricity without causing air pollution, it remains a dormant source of radiation hazards due to leakage in the reactor. Also the used fuel rods are to be carefully handled and disposed off as they still remain radioactive. The reserve of U is also limited and cannot last longer if its consumption continues at the present rate. Naturally search for alternative fissionable material continues. For example, plutonium (Pu) and (U) are fissionable. Although they are not directly available. Absorbing neutrons gets converted to fissionable plutonium Pu in the atomic reactor described above.

- **Disadvantages:**

✓ Although not much waste is produced, it is very, very dangerous.

✓ It must be sealed up and buried for many thousands of years to al ow the radioactivity to die away.

✓ For all that time it must be kept safe from earthquakes, flooding, terrorists and everything else. This is difficult.

✓ Nuclear power is reliable, but a lot of money has to be spent on safety - if it does go wrong, a nuclear accident can be a major disaster.

✓ People are increasingly concerned about this - in the 1990's nuclear power was the fastest-growing source of power in much of the world. In 2005 it was the second slowest-growing.

1.3 Non-conventional methods of power generation:

1.3.1 Fuel Cells:

A fuel cell is a device that converts the chemical energy from a fuel into electricity through a chemical reaction with oxygen or another oxidizing agent

Hydrogen produced from the steam methane reforming of natural gas is the most common fuel, but for greater efficiency hydrocarbons can be used directly such as natural gas and alcohols like methanol. Fuel cells are different from batteries in that they require a continuous source of fuel and oxygen/air to sustain the chemical reaction whereas in a battery the chemicals present in the battery react with each other to generate an electromotive (emf). Fuel cells can produce electricity continuously for as long as these inputs are supplied.

The first fuel cells were invented in 1838. The first commercial use of fuel cells came more than a century later in NASA space programs to generate power for probes, satellites and space capsules. Since then, fuel cells have been used in many other applications. Fuel cells are used for primary and backup power for commercial, industrial and residential buildings and in remote or inaccessible areas. They are also used to power fuel-cell vehicles, including forklifts, automobiles, buses, boats, motorcycles and submarines.

There are many types of fuel cells, but they all consist of an anode, a cathode and an electrolyte that allows charges to move between the two sides of the fuel cell. Electrons are drawn from the anode to the cathode through an external circuit, producing direct current electricity. As the main difference among fuel cell types is the electrolyte, fuel cells are classified by the type of electrolyte they use followed by the difference in startup time ranging from 1 sec for PEMFC to 10 min for SOFC. Fuel cells come in a variety of sizes. Individual fuel cells produce relatively small electrical potentials, about 0.7 volts, so cells are "stacked", or placed in series, to increase the voltage and meet an application's requirements.[2]In addition to electricity, fuel cells produce water, heat and, depending on the fuel source, very small amounts of nitrogen dioxide and other emissions. The energy efficiency of a fuel cell is generally between 40–60%, or up to 85% efficient in cogeneration if waste heat is captured for use.

Types:

Fuel cells come in many varieties; however, they all work in the same general manner. They are made up of three adjacent segments: the anode, the electrolyte, and the cathode. Two chemical reactions occur at the interfaces of the three different segments. The net result of the two reactions is that fuel is consumed, water or carbon dioxide is created, and an electric current is created, which can be used to power electrical devices, normally referred to as the load.

At the anode a catalyst oxidizes the fuel, usually hydrogen, turning the fuel into a positively charged ion and a negatively charged electron. The electrolyte is a substance specifically designed so ions can pass through it, but the electrons cannot. The freed electrons travel through a wire creating the electric current. The ions travel through the electrolyte to the cathode. Once reaching the cathode, the ions are reunited with the electrons and the two react with a third chemical, usually oxygen, to create water or carbon dioxide.

The electrolyte substance usually defines the type of fuel cell.

The fuel that is used. The most common fuel is hydrogen.

- The anode catalyst breaks down the fuel into electrons and ions. The anode catalyst is usually made up of very fine platinum powder.
- The cathode catalyst turns the ions into the waste chemicals like water or carbon dioxide. The cathode catalyst is often made up of nickel but it can also be a nonmaterial-based catalyst.

A typical fuel cell produces a voltage from 0.6 V to 0.7 V at full rated load. Voltage decreases as current increases, due to several factors:

- Activation loss
- Ohmic loss (voltage drop due to resistance of the cell components and interconnections)
- Mass transport loss (depletion of reactants at catalyst sites under high loads, causing rapid loss of voltage)

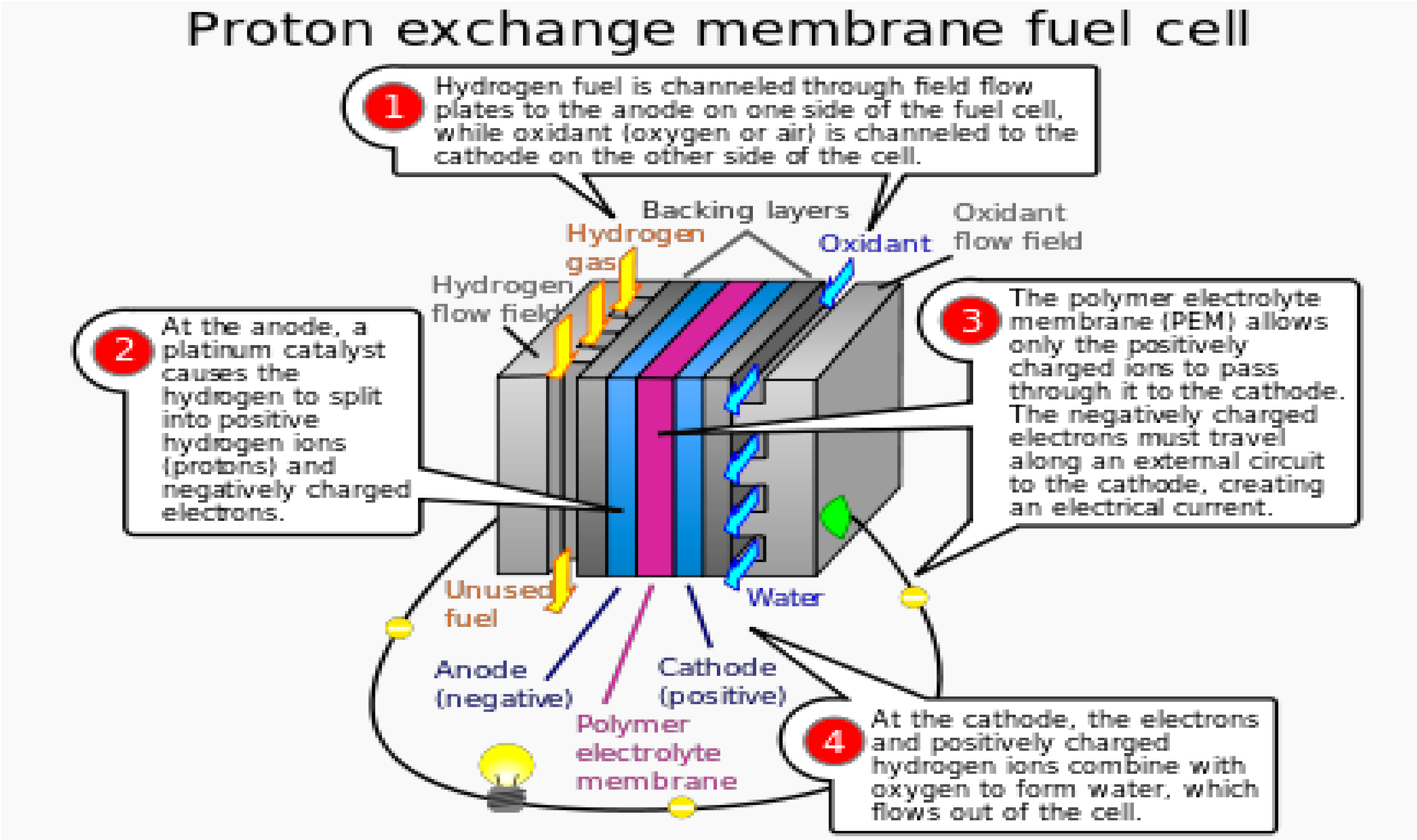
To deliver the desired amount of energy, the fuel cells can be combined in series to yield higher voltage, and in parallel to allow a higher current to be supplied. Such a design is called a fuel cell stack. The cell surface area can also be increased, to allow higher current from each cell. Within the stack, reactant gases must be distributed uniformly over each of the cells to maximize the power output.

i) Proton exchange membrane fuel cells (PEMFCs):

In the archetypical hydrogen–oxide proton exchange membrane fuel cell design, a proton-conducting polymer membrane (the electrolyte) separates the anode and cathode sides. This was called a "solid polymer electrolyte fuel cell" (SPEFC) in the early 1970s, before the proton exchange mechanism was well-understood.

On the anode side, hydrogen diffuses to the anode catalyst where it later dissociates into protons and electrons. These protons often react with oxidants causing them to become what are commonly referred to as multi-facilitated proton membranes. The protons are conducted through the membrane to the cathode, but the electrons are forced to travel in an external circuit (supplying power) because the membrane is electrically insulating. On the cathode catalyst, oxygen molecules react with the electrons (which have traveled through the external circuit) and protons to form water.

In addition to this pure hydrogen type, there are hydrocarbon fuels for fuel cells, including diesel, methanol and chemical hydrides. The waste products with these types of fuel are carbon dioxide and water, when hydrogen is used the CO2 is released when methane from natural gas is combined with steam in a process called steam methane reforming to produce the hydrogen, this can take place in a different location to the fuel cell potentially allowing the hydrogen fuel cell to be used indoors for example in forklifts.



Construction of a high-temperature PEMFC: Bipolar plate as electrode with in-milled gas channel structure, fabricated from conductive composites (enhanced with graphite, carbon black, carbon fiber, and/or carbon annotates for more conductivity) Porous carbon papers; reactive layer, usually on the polymer membrane applied; polymer membrane.

Condensation of water produced by a PEMFC on the air channel wall. The gold wire around the cell ensures the collection of electric current.

The different components of a PEMFC are;

1. Bipolar plates,
2. Electrodes,
3. Catalyst,
4. Membrane, and
5. The necessary hardware.

The materials used for different parts of the fuel cells differ by type. The bipolar plates may be made of different types of materials, such as, metal, coated metal, graphite, flexible graphite, C– C composite, carbon–polymer composites etc. The membrane electrode assembly (MEA) is referred as the heart of the PEMFC and is usually made of a proton exchange membrane sandwiched between two catalyst-coated carbon papers. Platinum and/or similar type of noble metals are usually used as the catalyst for PEMFC. The electrolyte could be a polymer membrane.

ii) Phosphoric acid fuel cell (PAFC):

Phosphoric acid fuel cells (PAFC) were first designed and introduced in 1961 by G. V. Elmore and H. A. Tanner. In these cells phosphoric acid is used as a non-conductive electrolyte to pass positive hydrogen ions from the anode to the cathode. These cells commonly work in temperatures of 150 to 200 degrees Celsius. This high temperature will cause heat and energy loss if the heat is not removed and used properly. This heat can be used to produce steam for air conditioning systems or any other thermal energy consuming system.[31] Using this heat incogeneration can enhance the efficiency of phosphoric acid fuel cells from 40– 50% to about 80%.Phosphoric acid, the electrolyte used in PAFCs, is a non-conductive liquid acid which forces electrons to travel from anode to cathode through an external electrical circuit. Since the hydrogen ion production rate on the anode is small, platinum is used as catalyst to increase this ionization rate. A key disadvantage of these cells is the use of an acidic electrolyte. This increases the corrosion or oxidation of components exposed to phosphoric acid.

iii) High-temperature fuel cells:

1) **Solid oxide fuel cells** (SOFCs):

Solid oxide fuel cells (SOFCs) use a solid material, most commonly a ceramic material called yttria-stabilized zirconia (YSZ), as the electrolyte. Because SOFCs are made entirely of solid materials, they are not limited to the flat plane configuration of other types of fuel cells and are often designed as rolled tubes. They require high operating temperatures (800–1000 °C) and can be run on a variety of fuels including natural gas.

SOFCs are unique since in those, negatively charged oxygen ions travel from the cathode (positive side of the fuel cell) to the anode (negative side of the fuel cell) instead of positively charged hydrogen ions travelling from the anode to the cathode, as is the case in all other types of fuel cells. Oxygen gas is fed through the cathode, where it absorbs electrons to create oxygen ions. The oxygen ions then travel through the electrolyte to react with hydrogen gas at the anode. The reaction at the anode produces electricity and water as by-products. Carbon dioxide may also be a by-product depending on the fuel, but the carbon emissions from an SOFC system are less than those from a fossil fuel combustion plant. The chemical reactions for the SOFC system can be expressed as follows.

$$2H_2 + 2O^{2-} \rightarrow 2H_2O + 4e^-$$

$$O_2 + 4e^- \rightarrow 2O^{2-}$$

$$2H_2 + O_2 \rightarrow 2H_2O$$

SOFC systems can run on fuels other than pure hydrogen gas. However, since hydrogen is necessary for the reactions listed above, the fuel selected must contain hydrogen atoms. For the fuel cell to operate, the fuel must be converted into pure hydrogen gas. SOFCs are capable of internally reforming light hydrocarbons such as methane (natural gas), propane and butane. These fuel cells are at an early stage of development.

Challenges exist in SOFC systems due to their high operating temperatures. One such challenge is the potential for carbon dust to build up on the anode, which slows down the internal reforming process. Research to address this "carbon coking" issue at the University of Pennsylvania has shown that the use of copper-based cermet (heat-resistant materials made of ceramic and metal) can reduce coking and the loss of performance. Another disadvantage of SOFC systems is slow start-up time, making SOFCs less useful for mobile applications. Despite these disadvantages, a high operating temperature provides an advantage by removing the need for a precious metal catalyst like platinum, thereby reducing cost. Additionally, waste heat from SOFC systems may be captured and reused, increasing the theoretical overall efficiency to as high as 80%–85%.

The high operating temperature is largely due to the physical properties of the YSZ electrolyte. As temperature decreases, so does the ionic conductivity of YSZ. Therefore, to obtain optimum performance of the fuel cell, a high operating temperature is required. According to their website, Ceres Power, a UK SOFC fuel cell manufacturer, has developed a method of reducing the operating temperature of their SOFC system to 500–600 degrees Celsius. They replaced the commonly used YSZ electrolyte with a CGO (cerium gadolinium oxide) electrolyte. The lower operating temperature allows them to use stainless steel instead of ceramic as the cell substrate, which reduces cost and start-up time of the system.

2) Hydrogen-Oxygen Fuel Cell:

The Hydrogen-Oxygen Fuel Cell was designed by Bacon in the year 1959. It was used as a primary source of electrical energy in the Apollo space program. The cell consists of two porous carbon electrodes impregnated with a suitable catalyst such as Pt, Ag, CoO, etc. The space between the two electrodes is filled with a concentrated solution of KOH or NaOH which serves as an electrolyte. $2H_2$ gas and O_2 gas are bubbled into the electrolyte through the porous carbon electrodes. Thus the overall reaction involves the combination of hydrogen gas and oxygen gas to form water. The cell runs continuously until the reactant's supply is exhausted. This type of cell operates efficiently in the temperature range 343 K to 413 K and provides a potential of about 0.9 V.

3) Molten carbonate fuel cells:

Molten carbonate fuel cells (MCFCs) require a high operating temperature, 650 °C (1,200 °F), similar to SOFCs. MCFCs use lithium potassium carbonate salt as an electrolyte, and this salt liquefies at high temperatures, allowing for the movement of charge within the cell – in this case, negative carbonate ions. Like SOFCs, MCFCs are capable of converting fossil fuel to a hydrogen-rich gas in the anode, eliminating the need to produce hydrogen externally. The reforming process creates CO 2emissions. MCFC-compatible fuels include natural gas, biogas and gas produced from coal. The hydrogen in the gas reacts with carbonate ions from the electrolyte to produce water, carbon dioxide, electrons and small amounts of other chemicals. The electrons travel through an external circuit creating electricity and return to the cathode. There, oxygen from the air and carbon dioxide recycled from the anode react with the electrons to form carbonate ions that replenish the electrolyte, completing the circuit.[43] The chemical reactions for an MCFC system can be expressed as follows:

$$CO_3^{2-} + H_2 \rightarrow H_2O + CO_2 + 2e^-$$

$$CO_2 + \tfrac{1}{2}O_2 + 2e^- \rightarrow CO_3^{2-}$$

$$H_2 + \tfrac{1}{2}O_2 \rightarrow H_2O$$

As with SOFCs, MCFC disadvantages include slow start-up times because of their high operating temperature. This makes MCFC systems not suitable for mobile applications, and this technology will most likely be used for stationary fuel cell purposes. The main challenge of MCFC technology is the cells' short life span. The high-temperature and carbonate electrolyte lead to corrosion of the anode and cathode. These factors accelerate the degradation of MCFC components, decreasing the durability and cell life. Researchers are addressing this problem by exploring corrosion-resistant materials for components as well as fuel cell designs that may increase cell life without decreasing performance.

MCFCs hold several advantages over other fuel cell technologies, including their resistance to impurities. They are not prone to "carbon coking", which refers to carbon build-up on the anode those results in reduced performance by slowing down the internal fuel reforming process. Therefore, carbon-rich fuels like gases made from coal are compatible with the system. The Department of Energy claims that coal, itself, might even be a fuel option in the future, assuming the system can be made resistant to impurities such as sulfur and particulates that result from converting coal into hydrogen.[34] MCFCs also have relatively high efficiencies. They can reach a fuel-to-electricity efficiency of 50%, considerably higher than the 37–42% efficiency of a phosphoric acid fuel cell plant. Efficiencies can be as high as 65% when the fuel cell is paired with a turbine and 85% if heat is captured and used in a Combined Heat and Power (CHP) system.

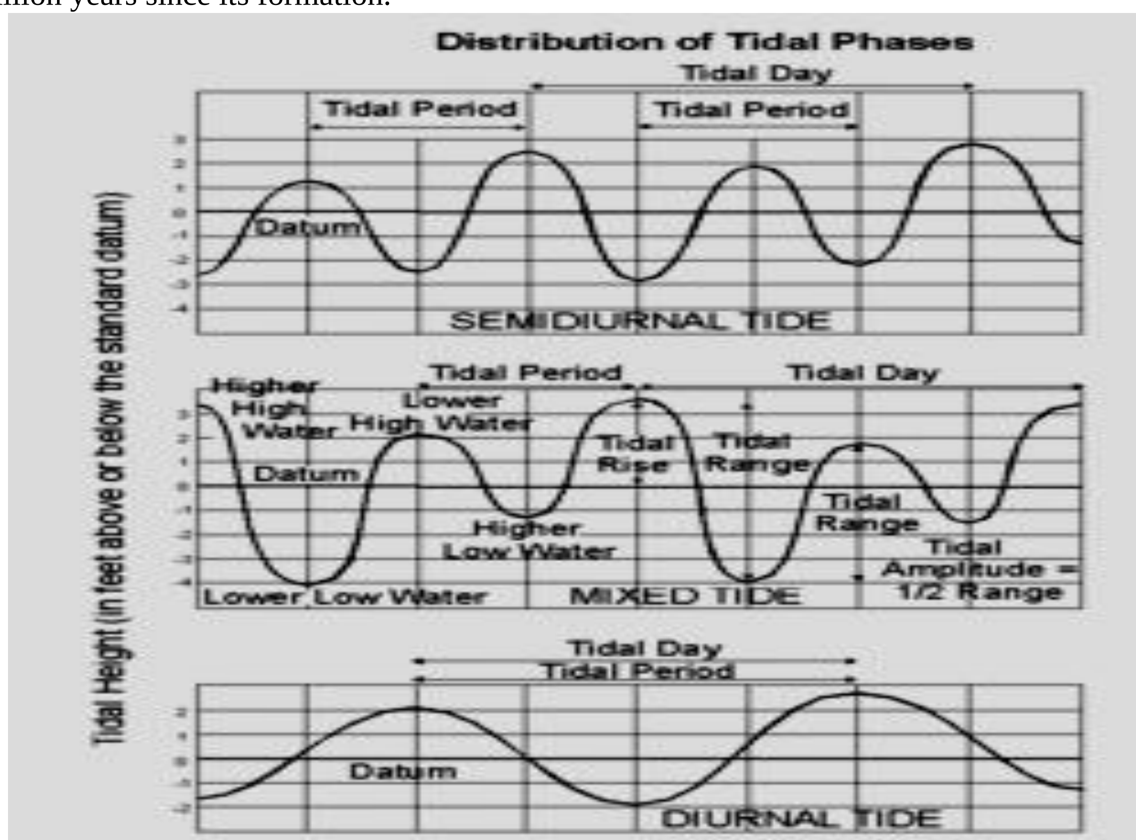
Fuel Cell Energy, a Connecticut-based fuel cell manufacturer, develops and sells MCFC fuel cells. The company says that their MCFC products range from 300 kW to 2.8 MW systems that achieve 47% electrical efficiency and can utilize CHP technology to obtain higher overall efficiencies. One product, the DFC-ERG, is combined with a gas turbine and, according to the company, it achieves an electrical efficiency of 65%.

1.3.2 Tidal Waves:

Tidal power is taken from the Earth's oceanic tides; tidal forces are periodic variations in gravitational attraction exerted by celestial bodies. These forces create corresponding motions or currents in the world's oceans. Due to the strong attraction to the oceans, a bulge in the water level is created, causing a temporary increase in sea level. When the sea level is raised, water from the middle of the ocean is forced to move toward the shorelines, creating a tide. This occurrence takes place in an unfailing manner, due to the consistent pattern of the moon's orbit around the earth.[5] The magnitude and character of this motion reflects the changing positions of the Moon and Sun relative to the Earth, the effects of Earth's rotation, and local geography of the sea floor and coastlines.

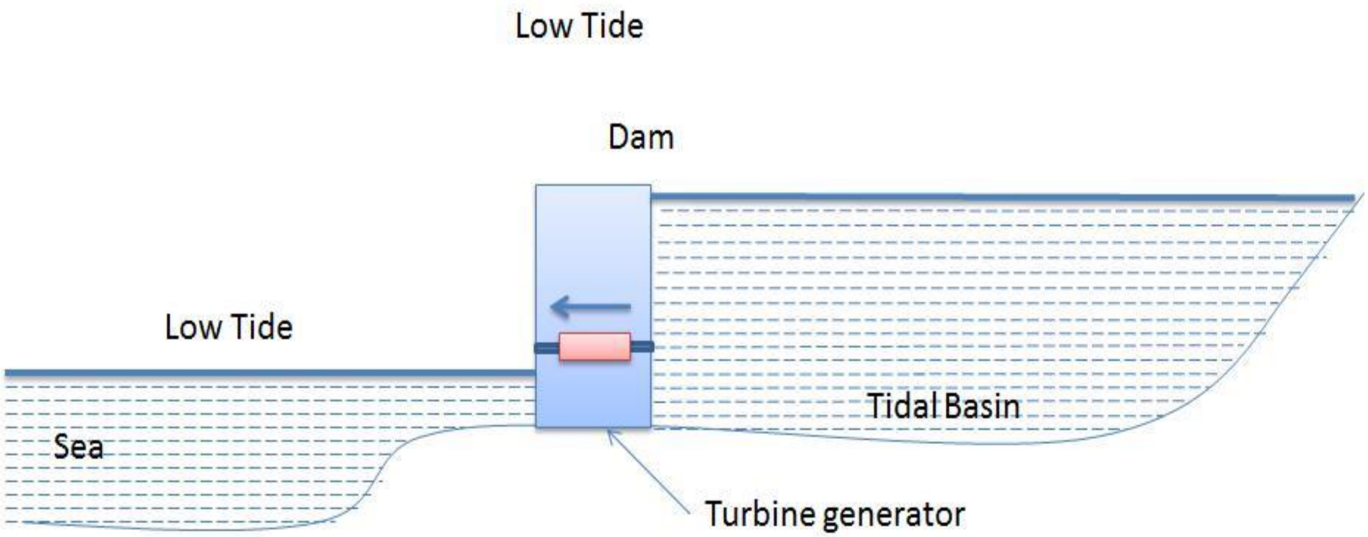
Tidal power is the only technology that draws on energy inherent in the orbital characteristics of the Earth–Moon system, and to a lesser extent in the Earth–Sun system. Other natural energies exploited by human technology originate directly or indirectly with the Sun, including fuel, conventional, wind, biofuel, wave and solar energy. Nuclear energy makes use of Earth's mineral deposits of fissionable elements, while geothermal power taps the Earth's internal heat, which comes from a combination of residual heat from planetary accretion (about 20%) and heat produced through radioactive decay (80%).

A tidal generator converts the energy of tidal flows into electricity. Greater tidal variation and higher tidal current velocities can dramatically increase the potential of a site for tidal electricity generation. Because the Earth's tides are ultimately due to gravitational interaction with the Moon and Sun and the Earth's rotation, tidal power is practically inexhaustible and classified as a renewable energy resource. Movement of tides causes a loss of mechanical energy in the Earth–Moon system: this is a result of pumping of water through natural restrictions around coastlines and consequent viscous dissipation at the seabed and inturbulence. This loss of energy has caused the rotation of the Earth to slow in the 4.5 billion years since its formation.



Tidal stream generator:

Tidal stream generators (or TSGs) make use of the kinetic energy of moving water to power turbines, in a similar way to wind turbines that use wind to power turbines. Some tidal generators can be built into the structures of existing bridges, involving virtually no aesthetic problems. Land constrictions such as straits or inlets can create high velocities at specific sites, which can be captured with the use of turbines. These turbines can be horizontal, vertical, open, or ducted and are typically placed near the bottom of the water column.



Tidal barrage

Tidal barrages make use of the potential energy in the difference in height (or hydraulic head) between high and low tides. When using tidal barrages to generate power, the potential energy from a tide is seized through strategic placement of specialized dams. When the sea level rises and the tide begins to come in, the temporary increase in tidal power is channeled into a large basin behind the dam, holding a large amount of potential energy. With the receding tide, this energy is then converted into mechanical energy as the water is released through large turbines that create electrical power through the use of generators. Barrages are essentially dams across the full width of a tidal estuary.

Dynamic tidal power

Dynamic tidal power (or DTP) is an untried but promising technology that would exploit an interaction between potential and kinetic energies in tidal flows. It proposes that very long dams (for example: 30– 50 km length) be built from coasts straight out into the sea or ocean, without enclosing an area. Tidal phase differences are introduced across the dam, leading to a significant water-level differential in shallow coastal seas – featuring strong coast-parallel oscillating tidal currents such as found in the UK, China, and Korea.

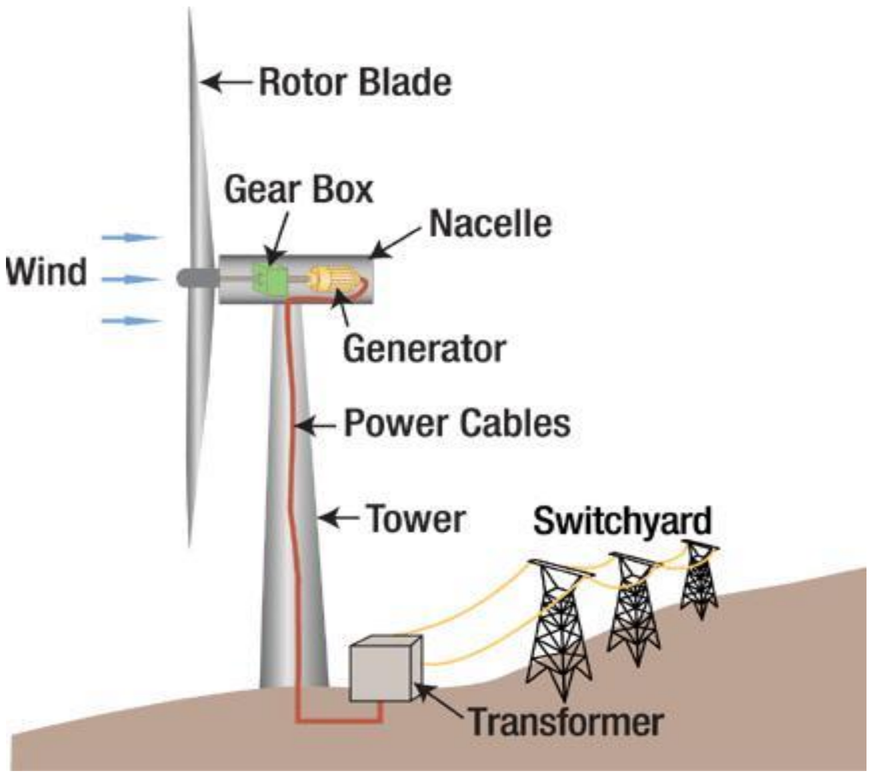
Tidal lagoon

A newer tidal energy design option is to construct circular retaining walls embedded with turbines that can capture the potential energy of tides. The created reservoirs are similar to those of tidal barrages, except that the location is artificial and does not contain a preexisting ecosystem.

1.3.3 Wind Power Generation:

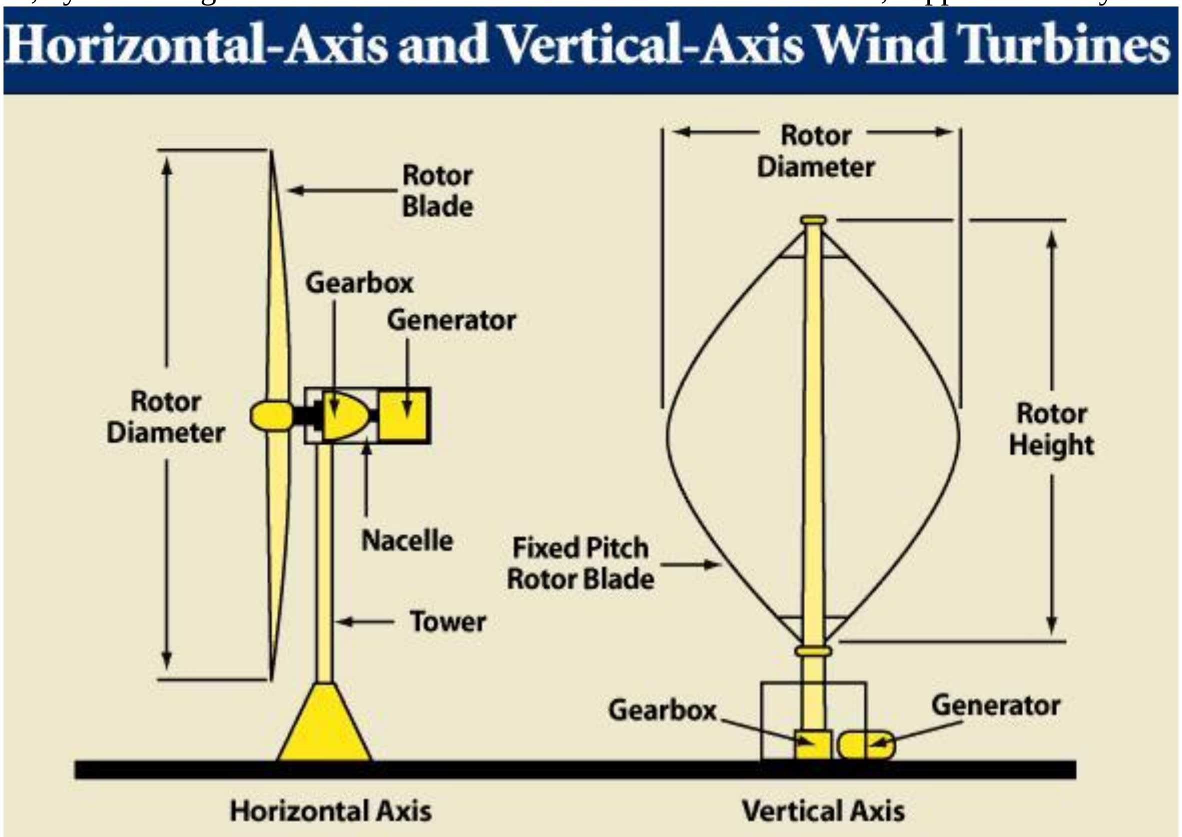
Horizontal axis:

Horizontal-axis wind turbines (HAWT) have the main rotor shaft and electrical generator at the top of a tower, and must be pointed into the wind. Small turbines are pointed by a simple wind vane, while large turbines generally use a wind sensor coupled with a servo motor. Most have a gearbox, which turns the slow rotation of the blades into a quicker rotation that is more suitable to drive an electrical generator.
Since a tower produces turbulence behind it, the turbine is usually positioned upwind of its supporting tower. Turbine blades are made stiff to prevent the blades from being pushed into the tower by high winds. Additionally, the blades are placed a considerable distance in front of the tower and are sometimes tilted forward into the wind a small amount.



Downwind machines have been built, despite the problem of turbulence (mast wake), because they don't need an additional mechanism for keeping them in line with the wind, and because in high winds the blades can be allowed to bend which reduces their swept area and thus their wind resistance. Since cyclical (that is repetitive) turbulence may lead to fatigue failures, most HAWTs are of upwind design.

Turbines used in wind farms for commercial production of electric power are usually three-bladed and pointed into the wind by computer-controlled motors. These have high tip speeds of over 320 km/h (200 mph), high efficiency, and low torque ripple, which contribute to good reliability. The blades are usually colored white for daytime visibility by aircraft and range in length from 20 to 40 meters (66 to 131 ft) or more. The tubular steel towers range from 60 to 90 meters (200 to 300 ft) tall. The blades rotate at 10 to 22 revolutions per minute. At 22 rotations per minute the tip speed exceeds 90 meters per second (300 ft/s).A gear box is commonly used for stepping up the speed of the generator, although designs may also use direct drive of an annular generator. Some models operate at constant speed, but more energy can be collected by variable-speed turbines which use a solid-state power converter to interface to the transmission system. All turbines are equipped with protective features to avoid damage at high wind speeds, by feathering the blades into the wind which ceases their rotation, supplemented by brakes.



Vertical axis:

Vertical-axis wind turbines (or VAWTs) have the main rotor shaft arranged vertically. One advantage of this arrangement is that the turbine does not need to be pointed into the wind to be effective, which is an advantage on a site where the wind direction is highly variable. It is also an advantage when the turbine is integrated into a building because it is inherently less steerable. Also, the generator and gearbox can be placed near the ground, using a direct drive from the rotor assembly to the ground-based gearbox, improving accessibility for maintenance.

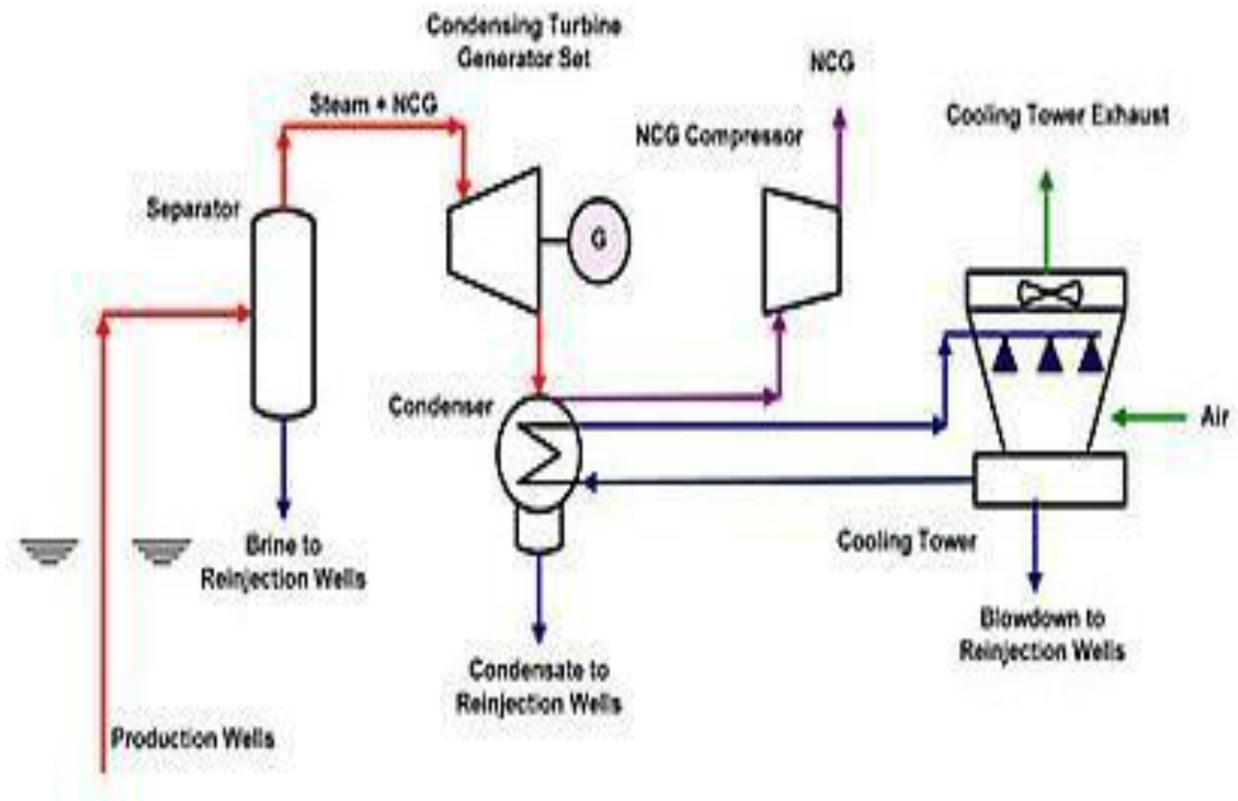
The key disadvantages include the relatively low rotational speed with the consequential higher torque and hence higher cost of the drive train, the inherently lower power coefficient, the 360 degree rotation of the aerofoil within the wind flow during each cycle and hence the highly dynamic loading on the blade, the pulsating torque generated by some rotor designs on the drive train, and the difficulty of modeling the wind flow accurately and hence the challenges of analyzing and designing the rotor prior to fabricating a prototype.

When a turbine is mounted on a rooftop the building generally redirects wind over the roof and this can double the wind speed at the turbine. If the height of a rooftop mounted turbine tower is approximately 50% of the building height it is near the optimum for maximum wind energy and minimum wind turbulence. Wind speeds within the built environment are generally much lower than at exposed rural sites, noise may be a concern and an existing structure may not adequately resist the additional stress.

1.3.4 Geothermal Power Generation:

- **Flashed steam/dry steam condensing system**; resource temperature range from about 320°C to some 230°C.
- **Flashed steam back pressure system**; resource temperature range from about 320°C to some 200°C.
- **Binary or twin-fluid system** (based upon the Kalian or the Organic Rankin cycle); resource temperature range between 120°C to about 190°C.

- ➢ **Power house equipment:** Comprising of turbine/generator unit complete with condenser, gas exhaust system.
- ➢ **Automatic control and communication system:** Consisting of frequency control, servo valve control, computer system for data collection, resource and maintenance monitoring, internal and external communication etc.
- ➢ **Cooling system:** Cooling water pumps, condensate pumps, fresh water (seawater) cooling, or cooling towers.
- ➢ **Particulate and/or droplet erosion:** This is an erosion problem that is typically associated with the parts of the system where the fluid is accelerated (e.g. in control valves, turbine nozzles, etc.) and/or abruptly made change direction (e.g. via pipe bends, T-fittings or wanes).
- ➢ **Heat exchangers:** These are either of the plate or the tube and shell type. These are generally only used in binary and hybrid type conversion systems, and/or in integrated systems.
- ➢ **Gas evacuation systems:** High temperature geothermal fluid contains a significant quantity of non-condensable gases (C02, N2, H2S, and others). These have to be removed for instance from the condensing plant for reasons of conversion efficiency. Some countries require the gas to be cleaned of H2S or Hg to minimize atmospheric pollution.
- ➢ **Re-injection system:** Comprising liquid effluent collection pipelines, injection pumps, injection pipelines, injection wells and control system.
- ➢ **Chemical injection system:** In order to reduce scaling of calcite in production wells sometimes a scale inhibitor is injected through capillary tubing down hole. Similar injection is applied with caustic soda to neutralize acid wells to reduce the corrosively. Acid is used for pH modification in order to arrest the scaling of silica in waste water going to reinjection, for cases where the water is supersaturated.



Power House equipment:

Turbine:

- The problems potentially associated with the turbine are scaling of the flow control valve and nozzles (primarily in the stator inlet stage); stress corrosion of rotor blades; erosion of turbine (rotor and stator) blades and turbine housing.
- The rate and seriousness of scaling in the turbine are directly related to the steam cleanliness, i.e. the quantity and characteristics of separator “carry-over“. Thus the operation and efficiency of the separator are of great importance to trouble free turbine operation. Prolonged operation of the power plant off-design point also plays a significant role.

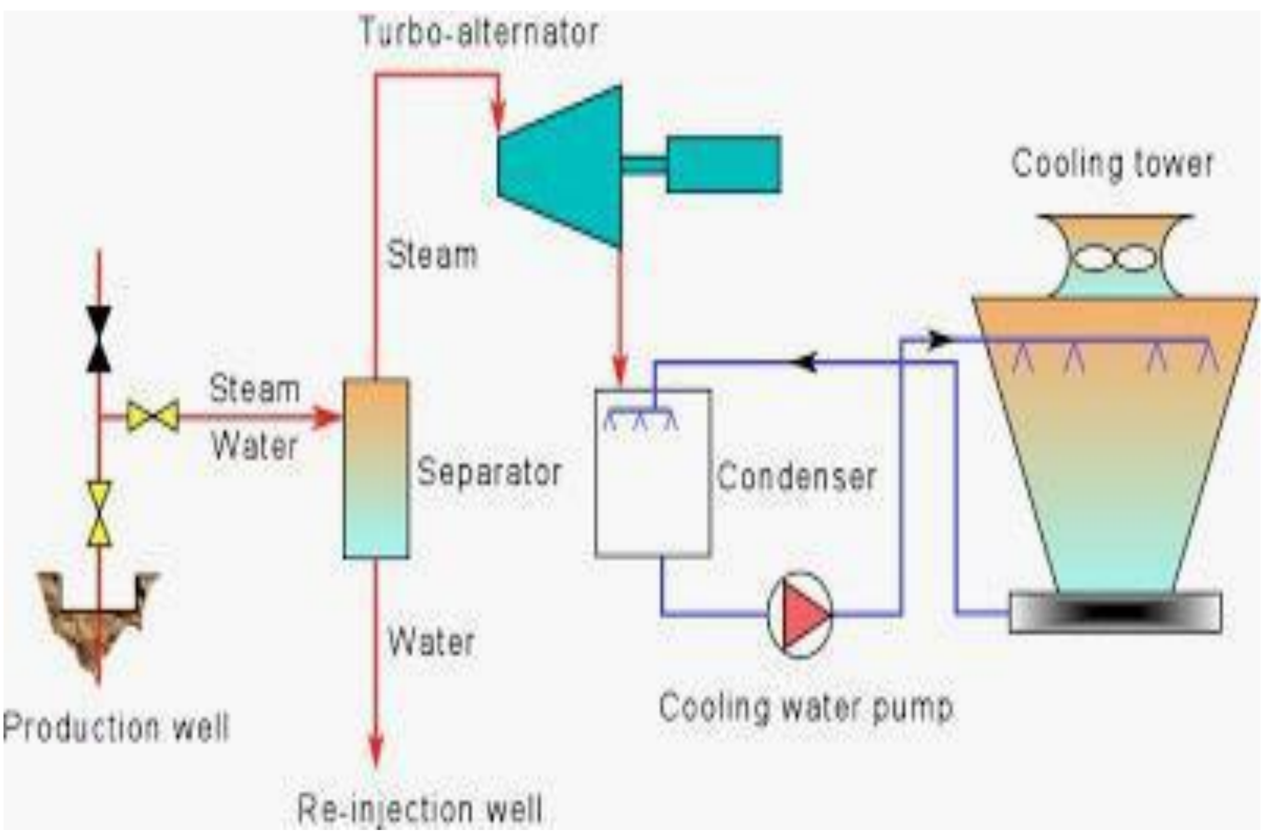
Generator:

- It must be pointed out here that high-temperature steam contains a significant amount of carbon dioxide CO2 and some hydrogen sulphite H2S and the atmosphere in geothermal areas is thus permeated by these gases.
- All electrical equipment and apparatus contains a lot of cuprous or silver components, which are highly suptible to sulphite corrosion and thus have to be kept in an H2S free environment. This is achieved by filtering the air entering the ventilation system and maintaining slight overpressure in the control room and electrical control centres.
- The power generator is either cooled by nitrogen gas or atmospheric air that has been cleaned of H2S by passage through special active carbon filter banks.

Condenser:

The steam-water mixture emitted from the turbine at outlet contains a significant amount of non condensable gases comprising mainly CO2 (which is usually 95–98% of the total gas content), CH4 and H2S, and is thus highly acidic.

- Since most high-temperature geothermal resources are located in arid or semi-arid areas far removed from significant freshwater (rivers, lakes) sources, the condenser cooling choices are mostly limited to either atmospheric cooling towers or forced ventilation ones.
- The application of evaporative cooling of the condensate results in the condensate containing dissolved oxygen in addition to the non-condensable gases, which make the condenser fluid highly corrosive and require the condenser to be clad on the inside with stainless steel; condensate pumpsto be made of stainless steel, and all condensate pipelines either of stainless steel or glass reinforced plastic.
- Addition of caustic soda is required to adjust the pH in the cooling tower circuit. Make-up water and blow-down is also used to avoid accumulation of salts in the water caused by evaporation.
- A problem sometimes encountered within the condenser is the deposition of almost pure sulphur on walls and nozzles within the condenser.
- This scale deposition must be periodically cleaned by high pressure water spraying etc.



Cooling tower and associated equipment:

Most high-temperature geothermal resources are located in arid or semi-arid areas far removed from significant freshwater (rivers, lakes) sources. This mostly limits condenser cooling choices to either atmospheric cooling towers or forced ventilation ones. Freshwater cooling from a river is, however, used for instance in New Zealand and seawater cooling from wells on Reykjanes, Iceland.

In older power plants the atmospheric versions and/or barometric ones, the large parabolic ones of concrete, were most often chosen. Most frequently chosen for modern power plants is the forced ventilation type because of environmental issues and local proneness to earth quakes.

The modern forced ventilation cooling towers are typically of wooden/plastic construction comprising several parallel cooling cells erected on top of a lined concrete condensate pond. The ventilation fans are normally vertical, reversible flow type and the cooling water pumped onto a platform at the top of the tower fitted with a large number of nozzles, through which the hot condensate drips in counterflow to the airflow onto and through the filling material in the tower and thence into the condensate pond, whence the cooled condensate is sucked by the condenser vacuum back into the condenser.

To minimise scaling and corrosion effects the condensate is neutralised through pH control, principally via addition of sodium carbonate.

Three types of problems are found to be associated with the cooling towers, i.e.

- Icing problems in cold areas.
- Sand blown onto the tower in sandy and arid areas.
- Clogging up by sulphitephylic bacteria.

➢ The first mentioned is countered by reversing the airflow cell by cell in rotation whilst operating thus melting off any icing and snow collecting on the tower.

➢ The second problem requires frequent cleaning of nozzles and condensate pond. The last mentioned is quite bothersome. It is most commonly alleviated by periodic application of bacteria killing chemicals, and cleaning of cooling tower nozzles by water jetting. The sludge accumulation in the condensate pond, however, is removed during scheduled maintenance stops. A secondary problem is the deposition of almost pure sulphur on walls and other surfaces within the condenser. It must be periodically cleaned by high pressure water spraying etc., which must be carried out during scheduled turbine stops.

Condenser pumping system:

- The condensate pumps must, as recounted previously, be made of highly corrosion resistant materials,and have high suction head capabilities**.** They are mostly trouble free in operation.
- The condensate pipes must also be made of highly corrosion resistant materials and all joints efficiently sealed to keep atmospheric air ingress to a minimum, bearing in mind that such pipes are all in a vacuum environment. Any air leakage increases the load on the gas evacuation system and thus the ancillary power consumption of the power plant.

Heat exchangers:

- In high-temperature power generation applications heat exchangers are generally not used on the well fluid. Their use is generally confined to ancillary uses such as heating, etc. using the dry steam. In cogeneration plants such as the simultaneous production of hot water and electricity, their use is universal.

- The exhaust from a back pressure turbine or tap-off steam from a process turbine is passed as primary fluid through either a plate or a tube and shell type heat exchanger.

- The plate type heat exchanger was much in favour in cogeneration plants in the seventies to nineties because of their compactness and high efficiency. They were, however, found to be rather heavy in maintenance.
- The second drawback was that the high corrosion resistance plate materials required were only able to withstand a relatively moderate pressure difference between primary and secondary heat exchanger media.
- Thirdly the plate seals tended to degenerate fairly fast and stick tenaciously to the plates making removal difficult without damaging the seals. The seals that were needed to withstand the required temperature and pressure were also pricy and not always in stock with the suppliers.
- This has led most plant operators to change over to and new plant designers to select the shell and tube configurations, which demand less maintenance and are easily cleaned than the plate type though requiring more room.
- In low-temperature binary power plants shell and tube heat exchangers are used to transfer the heat from the geothermal primary fluid to the secondary (binary) fluid. They are also used as condensers/and or regenerators in the secondary system.
- In supercritical geothermal power generation situation it is foreseen that shell and tube heat exchangers will be used to transfer the thermal energy of the supercritical fluid to the production of clean steam to power the envisaged power conversion system.

Gas evacuation system:

As previously stated the geothermal steam contains a significant quantity of non-condensable gas (NCG) or some 0.5% to 10% by weight of steam in the very worst case. To provide and maintain sufficient vacuum in the condenser, the NCG plus any atmospheric air leakage into the condenser must be forcibly exhausted. The following methods are typically adopted, viz.:

- The use of a single or two stage steam ejectors, economical for NCG content less than 1.5% by weight of steam.
- The use of mechanical gas pumps, such as liquid ring vacuum pumps, which are economical for high concentration of NCG.
- The use of hybrid systems incorporating methods 1 and 2 in series.
- The advantages of the ejector systems are the low maintenance, and high operational security of such systems.
- The disadvantage is the significant pressure steam consumption, which otherwise would be available for power production.
- The advantages of the vacuum pumps are the high degree of evacuation possible. The disadvantage isthe electric ancillary power consumption, sensitivity to particulate debris in the condenser, and high maintenance requirements.
- To reduce the ambient level of H2S in the proximity of the power plant, the exhausted NCG is currently in most countries discharged below the cooling tower ventilators to ensure a thorough mixing with the air as it is being blown high into the air and away from the power plant and its environs. In the USA and Italy H2S abatement is mandatory by law, and in Italy also mercury (Hg) and thus require chemical type abatement measures.
- In some of the older Geysers field power plants the H2S rich condenser exhaust was passed through abed of iron and zinc oxide to remove the H2S. These proved a very messy way of getting rid of the H2S and were mostly abandoned after a few years. In a few instances the Stretford process and other

equivalent ones have been used upstream of the power plant to convert H2S gas into sulphur for industrial use. This has proved expensive and complex and is not in use in other geothermal fields than the Geysers field in California.

- The main H2S abatement methods currently in use worldwide are (only some are currently used for geothermal NCG):

1. Claus (Selectox).
2. Haldor Topsöe – WSA process.
3. Shell-Paques Biological H2S removal process/THIOPAC.
4. LO-CAT (wet scrubbing liquid redox system).
5. Fe-Cl hybrid process.
6. Aqueous NaOH absorbent process.
7. Polar organic absorbent process.
8. Photo catalytic generation process.
9. Plasma chemical generation process.
10. Thermal decomposition process.
11. Membrane technology.

A study into feasible H2S abatement methods for the Nesjavellir Geothermal Project was carried outby Matthíasdóttir (2006). Matthíasdóttir and Gunnarsson, from the Iceland Technology Institute,came to the conclusion that of the above listed methods the following four merited further study for Nesjavellir, i.e the Haldor Topsöe-WSA, THIOPAQ (with bacteria), LO-CAT and the Fe-Cl hybrid process.

Re-injection system:

In most geothermal areas the geothermal fluid may be considered to be brine because of the typically high chloride content. It may also contain some undesirable tracer elements that pose danger to humans, fauna and flora.

In considering the most convenient way of disposing of this liquid effluent other than into effluentponds on the surface, the idea of injecting the liquid effluent back into the ground has been with the geothermal power industry for a long time (Stefánsson, 1997). Initially the purpose of re-injection was simply to get rid of the liquid effluent in a more elegant way than dumping it on the surface, into lakes or rivers, and even to the ocean. Many technical and economic drawbacks were soon discovered. The more serious of these were the clogging up of injection wells, injection piping and the formations close to the borehole; the cold effluent migrated into the production zone so reducing the enthalpy of the well output with consequent fall-off in power plant output. Injection into sandstone and other porous alluvial formations was and is fraught with loss of injectivity problems that are still not fully understood.

Soon, however, it became generally understood and accepted that returning the effluent liquid back into the reservoir had even greater additional benefits, viz.:

- Greatly reducing the rate of reservoir pressure and fluid yield decline.
- Improved extraction of the heat content contained within the reservoir formations.
- Reducing the fluid withdrawal effect on surface manifestations, e.g. hot pools, steam vents etc. All the above items serve to maintain resource sustainability and are thus of significant environmental benefit.

Re-injection should be considered an integral part of any modern, sustainable and environmentally friendly geothermal utilization, both as a method of effluent water disposal and to counteract pressure draw-down by providing artificial water recharge (Stefánsson, 1997). Re-injection is essential for sustainable utilization of virtually closed and limited recharge geothermal systems. Cooling of production wells, which is one of the dangers associated with re-injection, can be minimised though careful testing and research. Tracer testing, combined with comprehensive interpretation, is probably the most important tool for this purpose.

Many different methods have and are still being tried to overcome these technical problems mentioned above such as the use of settling tanks that promote polymerisation of the silica molecules and settling in the tanks prior to injection; injection of the effluent liquid directly from the separators at temperatures in the range of 145–160°C, so called “hot injection”, both to avoid contact with atmospheric air and to hinder scaling in the injection system; controlling the pH of the effluent commensurate with reduction in the rate of silica/calcite precipitation using acids and add condensate from the plant to dilute the silica in the brine, to name a few.

The danger of production well cooling can be minimised through careful testing and research. Tracer testing, combined with comprehensive interpretation, is probably the most important tool for this purpose. One way to delay the effects of cooling is also to locate the re-injection wells far enough away from the production area, say 2 km.

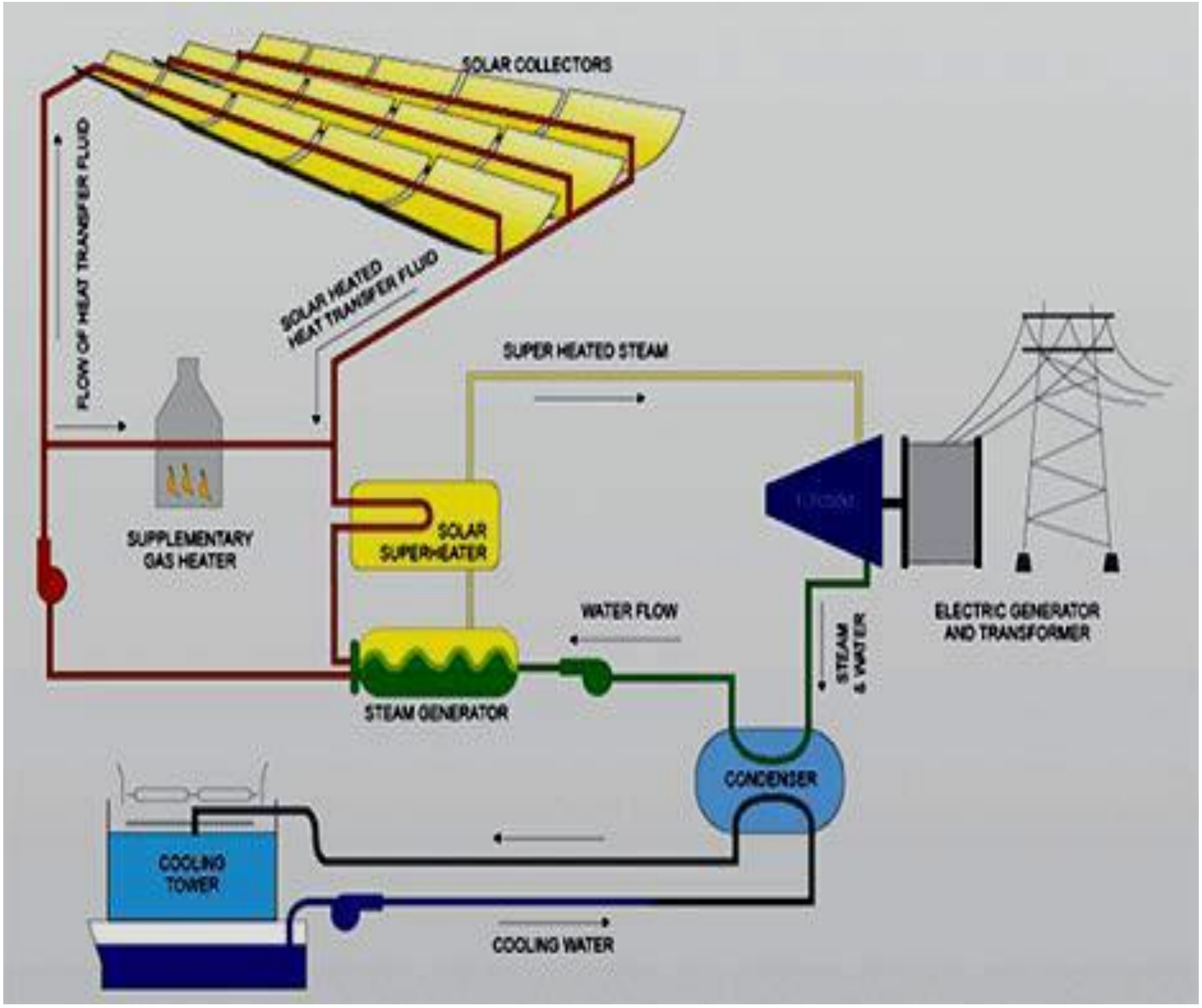
Another way gaining popularity is to inject deep into the reservoir, even where there is small permeability, by pumping at high pressures (60–100 bar).

Surface disposal contravenes the environmental statutes of most countries and the use of settling tanks has ceased mostly because of associated cost and complexity. The most commonly adopted injection methods are the last two, i.e. hot re-injection and chemical pH control ones. The main disadvantage of the hot re-injection technique is the lowered overall thermal efficiency and the consequent greater fluid production (more wells to yield the same power output) required. The main disadvantage of the pH control scheme is the very large acid consumption (cost) and uncertainties regarding its long-term effects.

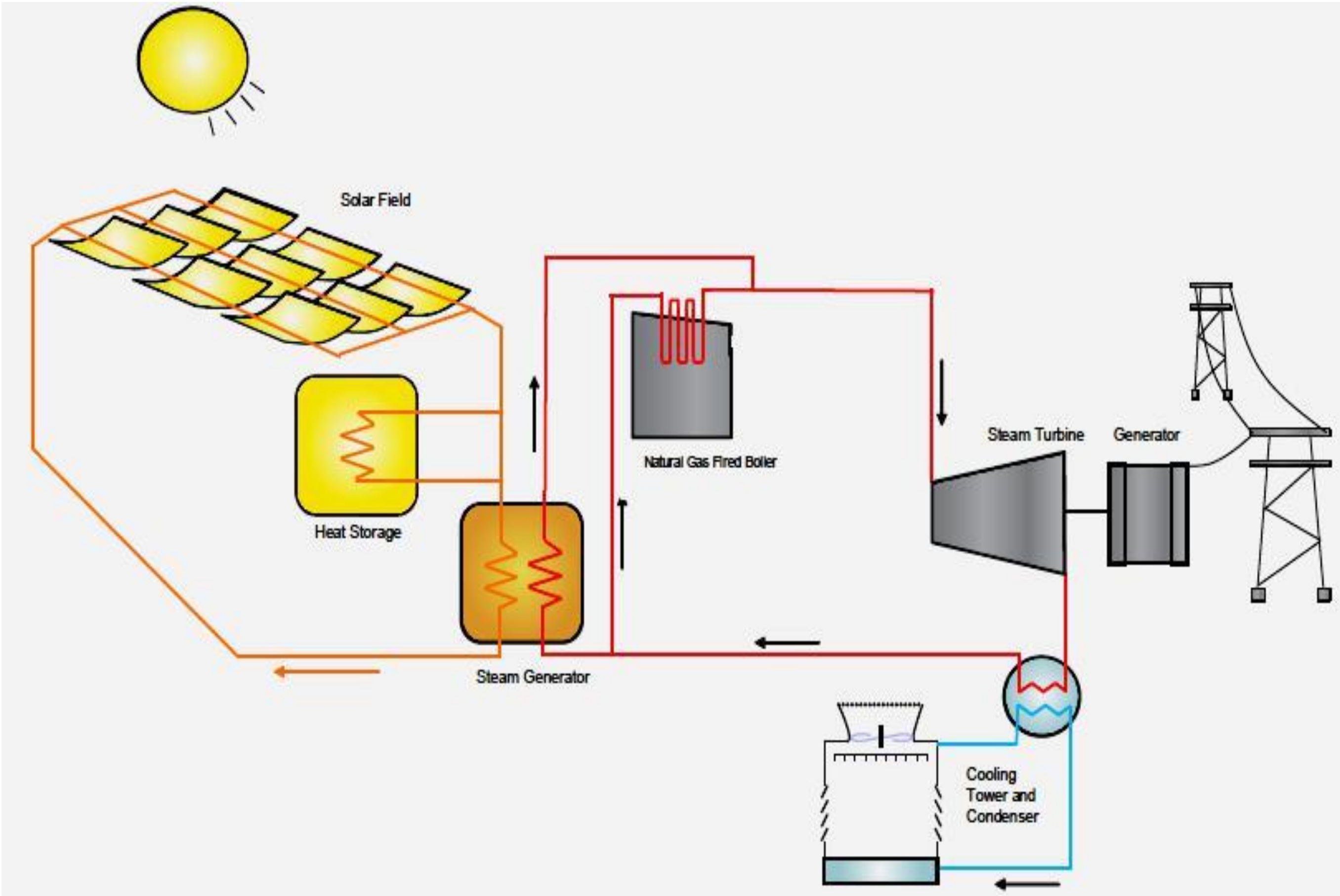
Hot re-injection is precluded in low-temperature power generation and the most common technique is to make use of the reverse solubility of calcite in water by operating the conversion system at a pressure level above the CO2 bubble point and only reduce the pressure once the fluid temperature has attained a level low enough to prevent calcite dissipation prior to re-injection.

1.3.5 Solar Power Generation:

Concentrating Solar Power (CSP) systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. The concentrated heat is then used as a heat source for a conventional power plant. A wide range of concentrating technologies exists: the most developed are the parabolic trough the concentrating linear fresnel reflector, the Stirling dish and the solar power tower. Various techniques are used to track the sun and focus light. In all of these systems a working fluid is heated by the concentrated sunlight, and is then used for power generation or energy storage. Thermal storage efficiently allows up to 24 hour electricity generation.



A parabolic trough consists of a linear parabolic reflector that concentrates light onto a receiver positioned along the reflector's focal line. The receiver is a tube positioned right above the middle of the parabolic mirror and is filled with a working fluid. The reflector is made to follow the sun during daylight hours by tracking along a single axis. Parabolic trough systems provide the best land-use factor of any solar technology.



Compact Linear Fresnel Reflectors are CSP-plants which use many thin mirror strips instead of parabolic mirrors to concentrate sunlight onto two tubes with working fluid. This has the advantage that flat mirrors can be used which are much cheaper than parabolic mirrors, and that more reflectors can be placed in the same amount of space, allowing more of the available sunlight to be used. Concentrating linear fresnel reflectors can be used in either large or more compact plants.

The Stirling solar dish combines a parabolic concentrating dish with a Stirling engine which normally drives an electric generator. The advantages of Stirling solar over photovoltaic cells are higher efficiency of converting sunlight into electricity and longer lifetime. Parabolic dish systems give the highest efficiency among CSP technologies. The 50 kW Big Dish in Canberra, Australia is an example of this technology.

A solar power tower uses an array of tracking reflectors (heliostats) to concentrate light on a central receiver atop a tower. Power towers are more cost effective, offer higher efficiency and better energy storage capability among CSP technologies. The PS10 Solar Power Plant and PS20 solar power plant are examples of this technology.

1.3.6 Biomass Power Generation:

Biomass is biological material derived from living, or recently living organisms. It most often refers to plants or plant-based materials which are specifically called lignocellulosic biomass. As an energy source, biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of biofuel. Conversion of biomass to biofuel can be achieved by different methods which are broadly classified into: thermal, chemical, and biochemical methods.

Wood remains the largest biomass energy source to date; examples include forest residues (such as dead trees, branches and tree stumps), yard clippings, wood chips and even municipal solid waste. In the second sense, biomass includes plant or animal matter that can be converted into fibers or other industrial chemicals, including biofuels. Industrial biomass can be grown from numerous types of plants, including miscanthus, switchgrass,hemp, corn, poplar, willow, sorghum, sugarcane, bamboo, and a variety of tree species, ranging from eucalyptus to oil palm (palm oil).

Plant energy is produced by crops specifically grown for use as fuel that offer high biomass output per hectare with low input energy. Some examples of these plants are wheat, which typically yield 7.5–8 tonnes of grain per hectare, and straw, which typically yield 3.5–5 tonnes per hectare in the UK. The grain can be used for liquid transportation fuels while the straw can be burned to produce heat or electricity. Plant biomass can also be degraded from cellulose to glucose through a series of chemical treatments, and the resulting sugar can then be used as a first generation biofuel.

Biomass can be converted to other usable forms of energy like methane gas or transportation fuels like ethanol and biodiesel. Rotting garbage, and agricultural and human waste, all release methane gas also called "landfill gas" or "biogas." Crops, such as corn and sugar cane, can be fermented to produce the transportation fuel, ethanol. Biodiesel, another transportation fuel, can be produced from left-over food products like vegetable oils and animal fats. Also, biomass to liquids (BTLs) and cellulosic ethanol are still under research.

There is a great deal of research involving algal, or algae-derived, biomass due to the fact that it's a non-food resource and can be produced at rates 5 to 10 times faster than other types of land-based agriculture, such as corn and soy. Once harvested, it can be fermented to produce biofuels such as ethanol, butanol, and methane, as well as biodiesel and hydrogen.

1.3.7 Municipal Waste:

The composition of municipal solid waste varies greatly from municipality to municipality (country to country) and changes significantly with time. In municipalities (countries) which have a well developed waste recycling culture, the waste stream consists mainly of intractable wastes such as plastic film, and un-recyclable packaging materials. At the start of the 20th century, the majority of domestic waste (53%) in the UK consisted of coal ash from open fires in developed municipalities (countries) without significant recycling activity it predominantly includes food wastes, market wastes, yard wastes, plastic containers and product packaging materials, and other millaneous solid wastes from residential, commercial, institutional, and industrial sources. Most definitions of municipal solid waste do not include industrial wastes, agricultural wastes, medical waste, radioactive waste or sewage sludge. Waste collection is performed by the municipality within a given area. The term residual waste relates to waste left from household sources containing materials that have not been separated out or sent for reprocessing. Waste can be classified in several ways but the following list represents a typical classification:

1. **Biodegradable waste:** food and kitchen waste, **green** waste, **paper** (can also be recycled).
2. **Recyclable material:** paper, glass, bottles, cans, metals, certain plastics, fabrics, clothes, batteries etc.
3. **Inert waste:** construction and demolition waste, **dirt,** rocks, **debris.**
4. **Electrical and electronic waste** (WEEE) - electrical appliances, TVs, computers, screens, etc.
5. **Composite wastes:** waste clothing, Tetra Packs, waste plastics such as toys.
6. Hazardous waste including most paints, chemicals, light bulbs, fluorent tubes, spray cans, fertilizer and containers
7. Toxic waste including pesticide, herbicides, fungicides
8. Medical waste.

1.4 Cogeneration:

Thermal power plants (including those that use fissile elements or burn coal, petroleum, or natural gas), and heat engines in general, do not convert all of their thermal energy into electricity. In most heat engines, a bit more than half is lost as excess heat (see: Second law of thermodynamics and Carnot's theorem). By capturing the excess heat, CHP uses heat that would be wasted in a conventional power plant, potentially reaching an efficiency of up to 80%, for the best conventional plants. This means that less fuel needs to be consumed to produce the same amount of useful energy.

Steam turbines for cogeneration are designed for extraction of steam at lower pressures after it has passed through a number of turbine stages, or they may be designed for final exhaust at back pressure (non-condensing), or both. A typical power generation turbine in apaper mill may have extraction pressures of 160 psig (1.103 MPa) and 60 psig (0.41 MPa). A typical back pressure may be 60 psig (0.41 MPa). In practice these pressures are custom designed for each facility. The extracted or exhaust steam is used for process heating, such as drying paper, evaporation, heat for chemical reactions or distillation. Steam at ordinary process heating conditions still has a considerable amount of enthalpy that could be used for power generation, so cogeneration has lost opportunity cost. Conversely, simply generating steam at process pressure instead of high enough pressure to generate power at the top end also has lost opportunity cost. The capital and operating cost of high pressure boilers, turbines and generators are substantial, and this equipment is normally operated continuously, which usually limits self-generated power to large-scale operations.

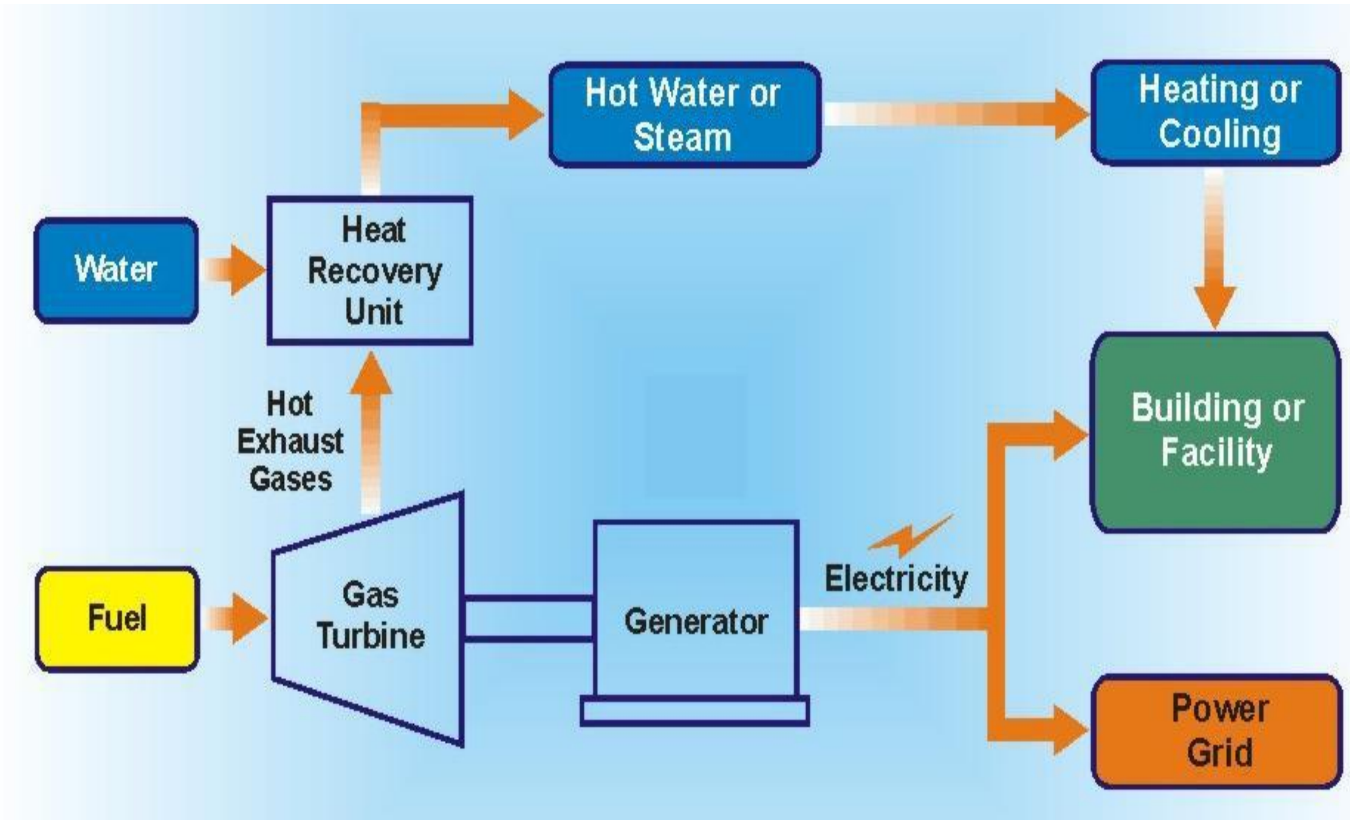
- Large cogeneration systems provide heating water and power for an industrial site or an entire town. Common CHP plant types are:
- Gas turbine CHP plants using the waste heat in the flue gas of gas turbines. The fuel used is typically natural gas
- Gas engine CHP plants use a reciprocating gas engine which is generally more competitive than a gas turbine up to about 5 MW. The gaseous fuel used is normally natural gas. These plants are generally manufactured as fully packaged units that can be installed within a plant room or external plant compound with simple connections to the site's gas supply and electrical distribution and heating systems. Biofuel engine CHP plants use an adapted reciprocating gas engine or diesel engine, depending upon which biofuel is being used, and are otherwise very similar in design to a Gas engine CHP plant. The advantage of using a biofuel is one of reduced hydrocarbon fuel consumption and thus reduced carbon emissions. These plants are generally manufactured as fully packaged units that can be installed within a plant room or external plant compound with simple connections to the site's electrical distribution and heating systems. Another variant is the wood gasifier CHP plant whereby a wood pellet or wood chip biofuel is gasified in a zero oxygen high temperature environment; the resulting gas is then used to power the gas engine.
- Combined cycle power plants adapted for CHP
- Molten-carbonate fuel cells and solid oxide fuel cells have a hot exhaust, very suitable for heating.
- Steam turbine CHP plants that use the heating system as the steam condenser for the steam turbine.
- Nuclear power plants, similar to other steam turbine power plants, can be fitted with extractions in the turbines to bleed partially expanded steam to a heating system. With a heating system temperature of 95 °C it is possible to extract about 10 MW heat for every MW electricity lost. With a temperature of 130 °C the gain is slightly smaller, about 7 MW for every MWe lost.

Heat recovery steam generators:

A heat recovery steam generator (HRSG) is a steam boiler that uses hot exhaust gases from the gas turbines or reciprocating engines in a CHP plant to heat up water and generate steam. The steam, in turn, drives a steam turbine or is used in industrial processes that require heat.

HRSGs used in the CHP industry are distinguished from conventional steam generators by the following main features:

- The HRSG is designed based upon the specific features of the gas turbine or reciprocating engine that it will be coupled to.
- Since the exhaust gas temperature is relatively low, heat transmission is accomplished mainly through convection.
- The exhaust gas velocity is limited by the need to keep head losses down. Thus, the transmission coefficient is low, which calls for a large heating surface area.
- Since the temperature difference between the hot gases and the fluid to be heated (steam or water) is low, and with the heat transmission coefficient being low as well, the evaporator and economizer are designed with plate fin heat exchangers.



Thermal Efficiency:

Every heat engine is subject to the theoretical efficiency limits of the Carnot cycle. When the fuel is natural gas, a gas turbine following the Brayton cycle is typically used. Mechanical energy from the turbine drives an electric generator. The low-grade (i.e. low temperature) waste heat rejected by the turbine is then applied to space heating or cooling or to industrial processes. Cooling is achieved by passing the waste heat to an absorption chiller.

Thermal efficiency in a trigeneration system is defined as:

$$\eta_{th} \equiv \frac{W_{out}}{Q_{in}} \equiv \frac{\text{Electrical Power Output} + \text{Heat Output} + \text{Cooling Output}}{\text{Total Heat Input}}$$

Where:

η_{th} = Thermal efficiency

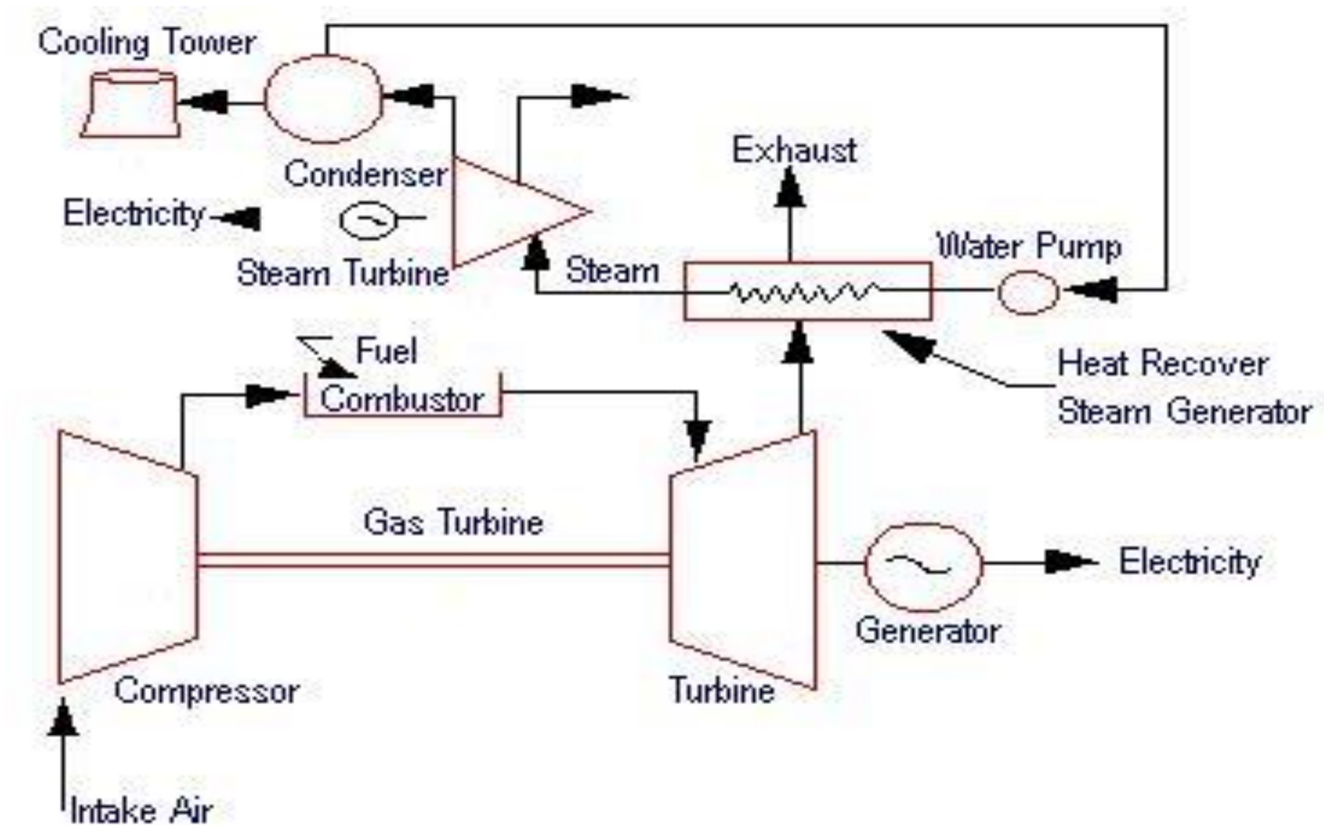
W_{out} = Total work output by all systems

Q_{in} = Total heat input into the system

Typical trigeneration models have losses as in any system. The energy distribution below is represented as a percent of total input energy

Electricity = 45% Heat + Cooling = 40% Heat Losses = 13%

Electrical Line Losses = 2%



Conventional central coal- or nuclear-powered power stations convert only about 33% of their input heat to electricity. The remaining 67% emerges from the turbines as low-grade waste heat with no significant local uses so it is usually rejected to the environment. These low conversion efficiencies strongly suggest that productive uses could be found for this waste heat, and in some countries these plants do collect byproduct heat that can be sold to customers.

But if no practical uses can be found for the waste heat from a central power station, e.g., due to distance from potential customers, then moving generation to where the waste heat can find uses may be of great benefit. Even though the efficiency of a small distributed electrical generator may be lower than a large central power plant, the use of its waste heat for local heating and cooling can result in an overall use of the primary fuel supply as great as 80%. This provides substantial financial and environmental benefits.

1.5 Effect of distributed generation on power system operation:

The introduction of DG in systems originally radial and designed to operate without any generation on the distribution system, can significantly impact the power flow and voltage conditions at both, customers and utility equipment.

These impacts can be manifested as having positive or negative influence, depending on the DG features and distribution system operation characteristics.

A method to asses this impact, is based on investigate the behaviour of an electric system, with and without the presence of DG. The difference between the results obtained in these two operating conditions, gives important information for both, companies in the electric sector and customers.

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1) Impact of DG on Voltage Regulation:

- Radial distribution systems regulate the voltage by the aid of load tap changing transformers (LTC) at substations, additionally by line regulators on distribution feeders and shunt capacitors on feeders or along the line. Voltage regulation is based on one way power flow where regulators are equipped with line drop compensation.
- The connection of DG may result in changes in voltage profile along a feeder by changing the direction and magnitude of real and reactive power flows. Nevertheless,
- DG impact on voltage regulation can be positive or negative depending on distribution system and distributed generator characteristics as well as DG location
- There are two possible solutions facing this problem: the first solution is to move the DG unit to the upstream side of the regulator, while the second solution is adding regulator controls to compensate for the DG output.

  The installation of DG units along the power distribution feeders may cause overvoltage due to too much injection of active and reactive power. For instance, a small DG system sharing a common distribution transformer with several loads may raise the voltage on the secondary side, which is sufficient to cause high voltage at these customers

2) Impact of DG on Losses:

- One of the major impacts of Distributed generation is on the losses in a feeder. Locating the DG units is an important criterion that has to be analyzed to be able to achieve a better reliability of the system with reduced losses

3) Impact of DG on Harmonics:

- A wave that does not follow a “pure” sinusoidal wave is regarded as harmonically distorted.

  Harmonics are always present in power systems to some extent. They can be caused by for instance: non-linearity in transformer exciting impedance or loads such as fluorent lights, AC to DC conversion equipment, variable-speed drives, switch mode power equipment, arc furnaces, and other equipment.

  Impact of DG on Short Circuit Levels of the Network

- The presence of DG in a network affects the short circuit levels of the network. It creates an increase in the fault currents when compared to normal conditions at which no DG is installed in the network
- The fault contribution from a single small DG is not large, but even so, it will be an increase in the fault current. In the case of many small units, or few large units, the short circuits levels can be altered enough to cause miss coordination between protective devices, like fuses or relays.The nature of the DG also ffects the short circuit levels.
- The highest contributing DG to faults is the synchronous generator. During the first few cycles its contribution is equal to the induction generator and self excited synchronous generator, while after the first few cycles the synchronous generator is the most fault current contributing DG type. The DG type that contributes the least amount of fault current is the inverter interfaced DG type, in some inverter types the fault contribution lasts for less than one cycle.

UNIT-2

ECONOMIC ASPECTS OF GENERATION

2.1 Economic aspects of power generation:

Introduction to Economics of Power Generation:

The function of a power station is to deliver power at the lowest possible cost per kilo watt hour. This total cost is made up of fixed charges consisting of interest on the capital, taxes, insurance, depreciation and salary of managerial staff, the operating expenses such as cost of fuels, water, oil, labor, repairs and maintenance etc.

1. The cost of power generation can be minimized by:
2. Choosing equipment that is available for operation during the largest possible % of time in a year.
3. Reducing the amount of investment in the plant.
4. Operation through fewer men.
5. Having uniform design
6. Selecting the station as to reduce cost of fuel, labor, etc.

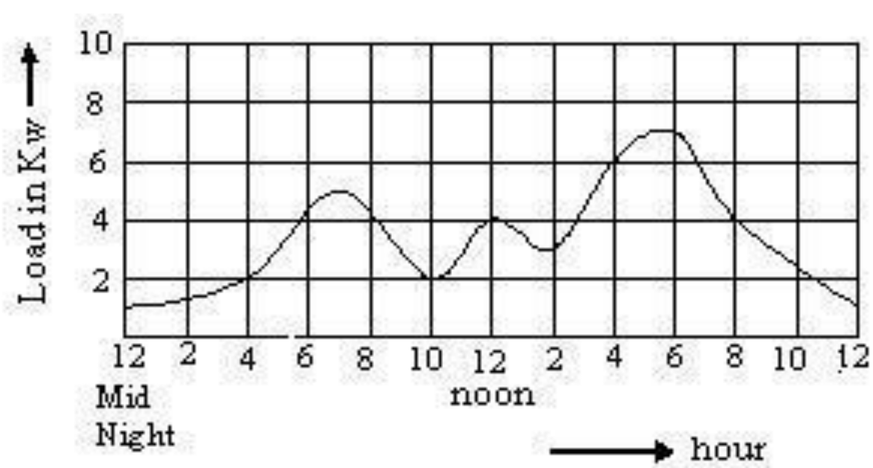
All the electrical energy generated in a power station must be consumed immediately as it cannotbe stored. So the electrical energy generated in a power station must be regulated according tothe demand. The demand of electrical energy or load will also vary with the time and a powerstation must be capable of meeting the maximum load at any time.

2.2 Load curve:

Load curve is plot of load in kilowatts versus time usually for a day or a year.

Definition:

The curve showing the variation of load on the power station with respect to time.



Types of load curves:

1. Daily load curve–Load variations during the whole day
2. Monthly load curve–Load curve obtained from the daily load curve
3. Yearly load curve-Load curve obtained from the monthly load curve

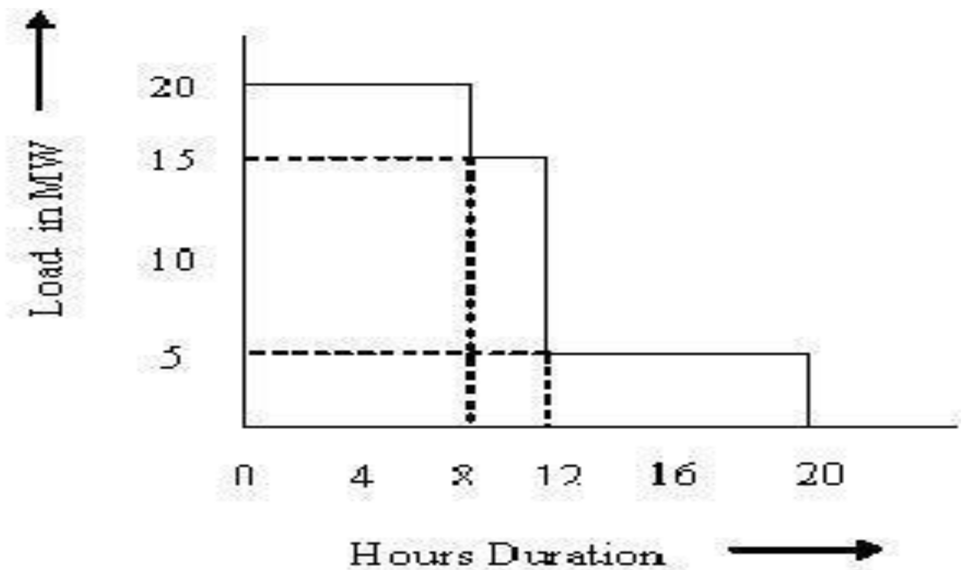
Load Characteristics:

- Connected load
- Maximum demand

- Average load
- Load factor
- Diversity factor
- Plant capacity factor
- Plant use factor

2.3 Load duration curve:

Load duration curve is the plot of load in kilowatts versus time duration for which it occurs. When the elements of a load curve are arranged in the order of dending magnitudes.



Number and Size of Units:

Maximum demand:

Maximum demand is the greatest of all demands which have occurred during a given period of time.

Average load:

Average load is is the average load on the power station in a given period (day/month or year)

Base load:

Base load is the minimum load over a given period of time.

Connected load:

Connected load of a system is the sum of the continuous ratings of the load consuming apparatus connected to the system.

Peak load:

Peak load is the maximum load consumed or produced by a unit or group of units in a stated period of time. It may be the maximum instantaneous load or the maximum average load over a designated interval of time.

Demand factor:

Demand factor is the ratio of maximum demand to the connected load of a consumer.

Diversity factor:

Diversity factor is the ratio of sum of individual maximum demands to the combined maximum demand on power stations

Load factor:

Load factor is the ratio of average load during a specified period to the maximum load occurring during the period.

Load factor = Average Load / Maximum demand

Station load factor:

Station load factor is the ratio of net power generated to the net maximum demand on a power station.

Plant factor:

Plant factor is the ratio of the average load on the plant for the period of time considered, to the aggregate rating of the generating equipment installed in the plant.

Capacity factor:

Capacity factor is the ratio of the average load on the machine for a period of time considered, to the rating of the machine.

Demand factor:

Demand factor is the ratio of maximum demand of system or part of system, to the total connected load of the system, or part of system, under consideration.

Cost of electrical energy:

Electric Energy is the source of energy for electrical appliances. Your computer, the cooling, and the lighting at your home are all powered by electric energy. Can you imagine life without electric energy? Do you even know how much it costs? Electric Energy is measured in kWh (kilowatt-hour) or MWh (megawatt-hour). Power is equal to work done in respect to time, so work equals power multiplied by time. Since work equals energy, electric energy would be measured by a kilowatt-hour.

P = W/t

W = E = Pt

(1000W)(1h) = 1kWh

The cost of each kWh depends on your location and the company you use. In New York, the average kWh costs 14.31 cents, but it can cost as high as 16.73 cents in Hawaii or as low as 5.81 cents in Kentucky. You're probably thinking that's not so expensive, but when it all adds up, the number can become significant. Just look at your electric bill. An electric bill in New York can come out to be $81.68, depending on which appliances are being used. But imagine you’re electric bill when you're blasting your air conditioner. It can cost you a few hundred dollars. But you candecrease that cost by using more of your fan in place of your air conditioner because a typical fan would cost you in the teens rather than in the hundreds. This is mainly due to the amount of watts used to power your electric appliances. An air conditioner can use up to a few thousand watts, while a fan would only use a few hundred watts. If you want to keep your electric bill low, substitute high watt appliances for low watt appliances

Tariff:

Tariff means the schedule of rates framed for supply of electrical energy to the various categories of consumers. All types of tariffs must cover the recovery of costs of

(i) Capital investment in generating, transmitting and distributing equipment

(ii) Operation, supplies and maintenance of equipment and

(ii) Metering equipment, billing, collection and miscall aneous services

(iv) A satisfactory return on the total capital investment.

(i) Flat Demand Tariff:

This is one of the earliest forms of tariffs used for charging the consumers for electrical energy consumption. This tariff is expressed as energy charges, y = Rs. Ax where a is the rate per lamp or kw of connected load and x is the number of lamps or load connected in kw. In these types of tariff the metering equipment, meter reading, billing, and accounting costs are eliminated. Now-a-days such a tariff is restricted to use such as in street lighting, signal systems, sign lightings etc.

(ii) Simple Tariff:

This is the simplest type of tariff according to which the cost o energy is charged on the basis of units consumed and can be expressed in the form y = Rs ax where a is charges in rupees per unit and x is the total electrical energy consumed in units or kwh.

(ii) Flat Rate Tariff:

This types of tariff differs from the former one in the sense that the different types of consumers are charged at different rates i.e. the flat rate for light and fan loads is slightly higher than that for power load. The rate for each category of consumers is arrived at by taking into account its load factor and diversity factor.

(iv)Step Rate Tariff:

The step rate tariff is a group of flat rate tariffs of decreasing unit charges for higher range of consumption.

(**vi) Hopkinson Demand Rate or Two Part Tariff**:

The total energy charge to be made to the consumer is split into two components namely fixed charge and runign charge. This type of tariff is expressed as

Y = Rs a kw + b kwh

Where Rs a is the charge per kw of maximum demand assessed and Rs b is the charge per kwh of energy consumed.

This tariff is mostly applicable to medium industrial consumers.

(vi) Maximum Demand Tariff:

This tariff is similar to that of two part tariff except that in this case maximum demand is actual y measured by a maximum demand indicator instead of merely assessing it on the basis of rate able value.

(vi i) KVA Maximum Demand Tariff:

It is a modified form of two part tariff. In tis case maximum demand is measured in Kva instead of in kw. This type of tariff encourages the consumers to operate their machines/equipment at improved power factor because low power factor wil cause more demand charges.

(ix) Doherty Rate or Three Part Tariff:

In this tariff total energy charge is split into three elements namely fixed charge, semi-fixed charge and variable charge. Such a tariff is expressed as

y = Rs a + bkw + c kwh.

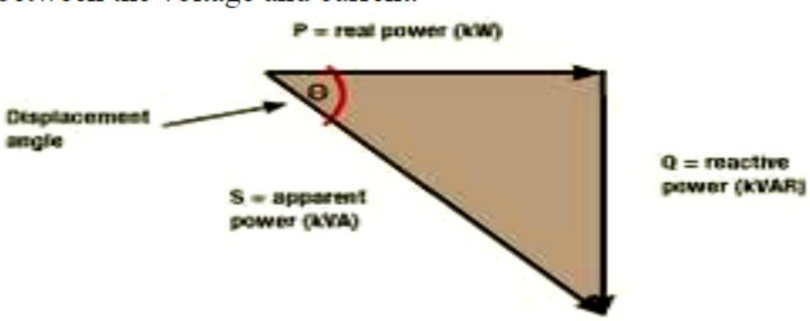
Where a is a constant charge, b is unit charge in Rs per kw of maximum demand in kw during bil ing period (in some case it is also charged in Rs per kva instead of Rs per kw) and c is the unit charge for energy in Rs per kwh of energy consumed. This type of tariff is usual y applicable to bulk supplies.

(x) Off Peak Tariff:

The load on the power station usual y has pronounced peak loads in the morning and early evening and a very low load during the night (from 10 P.M. to 6 A.M.). During the night, therefore, and other off-peak period which may occur, a large proportion of the generating and distribution equipment wil be lying idle. In case the consumers are encouraged to use electricity during off peak hours by giving a special discount, the energy can be supplied without incurring an additional capital cost and should therefore prove very profitable. This type of tariff is very advantageous for certain processes such as water heating by thermal storage, pumping, refrigeration.

Economics of power factor improvement:

Real power is considered the work-producing power measured in watts (W) or kilowatts (kW). For example, real power produces the mechanical output of a motor.
Reactive power is not used to do work, but is needed to operate equipment and is measured in volt-amperes-reactive (VAR) or kilovar (kVAR). Many industrial loads are inductive such as motors, transformers, fluorescent lighting ballasts, power electronics, and induction furnaces. The current drawn by an inductive load consists of two components: magnetizing current and power producing current. The magnetizing current is required to sustain the electromagnetic field in a device and creates reactive power. An inductive load draws current that lags the voltage, in that the current follows the voltage wave form. The amount of lag is the electrical displacement (or phase) angle between the voltage and current.



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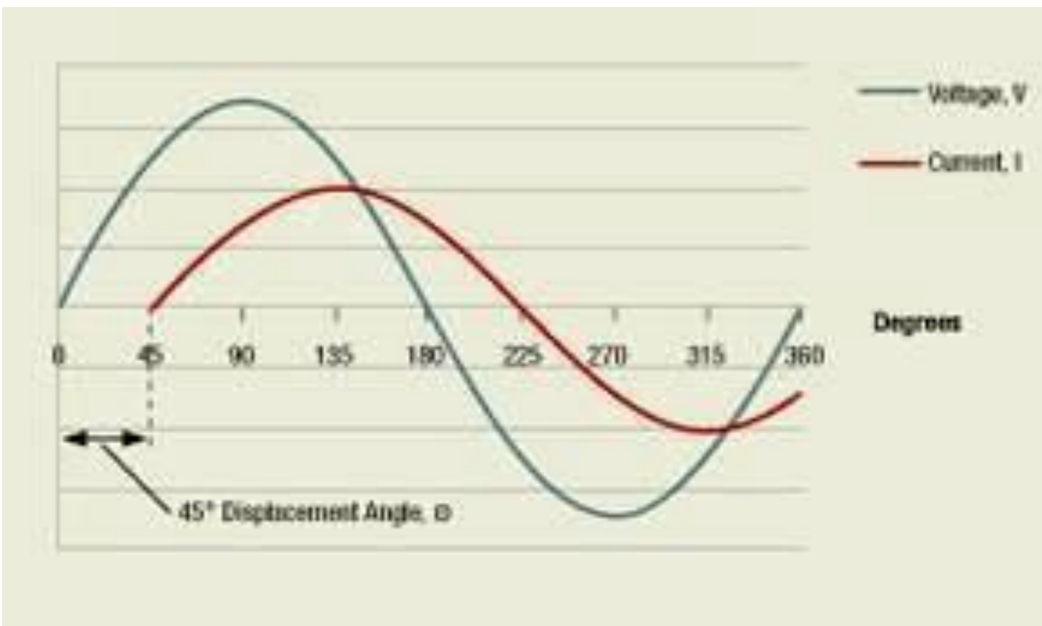
Power factor (PF) is the ratio of the real power to apparent power and represents how much real power electrical equipment uses. It is a measure of how effectively electrical power is being used. Power factor is also equal to the cosine of the phase angle between the voltage and current



Electrical loads demand more power than they consume. Induction motors convert at most 80% to 90% of the delivered power into useful work or electrical losses. The remaining power is used to establish an electromagnetic field in the motor. The field is alternately expanding and collapsing (once each cycle), so the power drawn into the field in one instant is returned to the electric supply system in the next instant. Therefore, the average power drawn by the field is zero, and reactive power does not register on a kilowatt-hour meter. The magnetizing current creates reactive power. Although it does no useful work, it circulates between the generator and the load and places a heavier drain on the power source as well as the transmission and distribution system.

As a means of compensation for the burden of supplying extra current, many utilities establish a power factor penalty in their rate schedule. A minimum power factor, usually 0.85 to 0.95, is

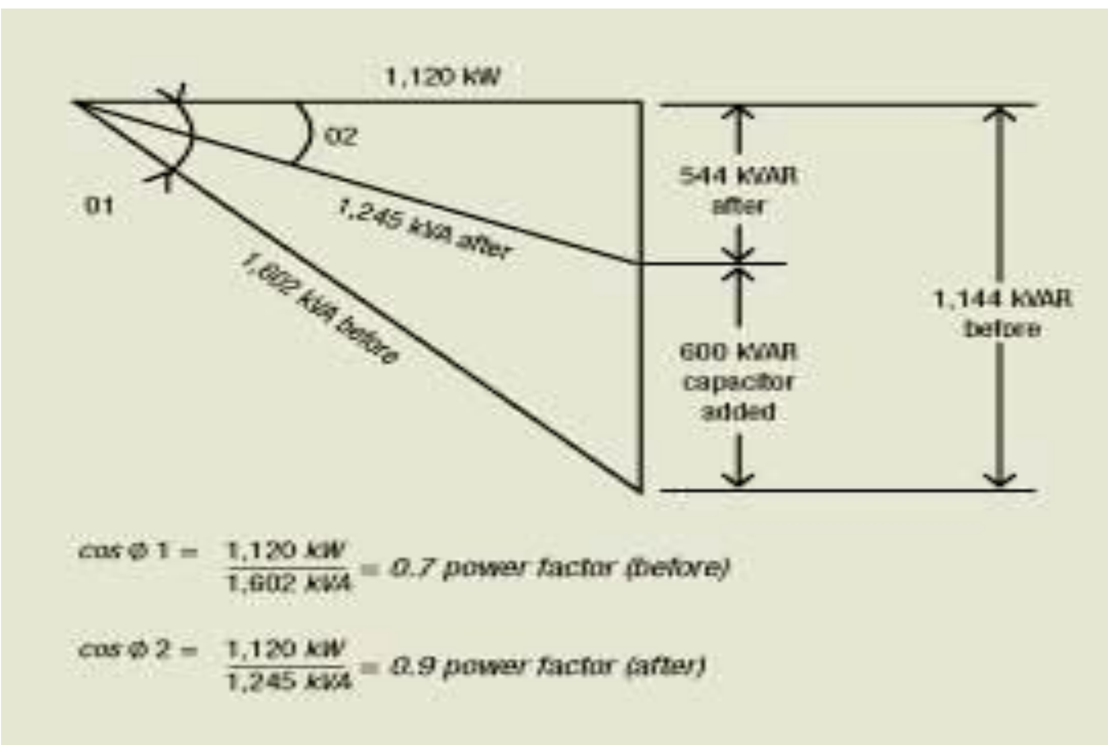
established. When a customer's power factor drops below the minimum value, the utility collects a low power factor revenue premium on the customer's bill. Another way some utilities collect a low power factor premium is to charge for kVA (apparent power) rather than kW (real power).
With a diverse range of billing rate structures imposed by electrical utilities especially for large users, it is imperative to fully understand the billing method employed.

Improving power factor:

Adding capacitors is generally the most economical way to improve a facility's power factor. While the current through an inductive load lags the voltage, current to a capacitor leads the voltage. Thus, capacitors serve as a leading reactive current generator to counter the lagging reactive current in a system.

The expression "release of capacity" means that as power factor of the system is improved, the total current flow will be reduced. This permits additional loads to be added and served by the existing system. In the event that equipment, such as transformers, cables, and generators, may be thermally overloaded, improving power factor may be the most economical way to reduce current and eliminate the overload condition.

Primarily, the cost-effectiveness of power factor correction depends on a utility's power factor penalties. It is crucial to understand the utility's rate structure to determine the return on investment to improve power factor.



Maintaining a high power factor in a facility will yield direct savings. In addition to reducing power factor penalties imposed by some utilities, there may be other economic factors that, when considered in whole, may lead to the addition of power factor correction capacitors that provide a justifiable return on investment. Other savings, such as decreased distribution losses, improved voltage reduction, and increased facility current carrying capacity, are less obvious. Though real, often these reductions yield little in cost savings and are relatively small in comparison to the savings to be gained from reducing power factor penalties.

Harmonic current considerations:

This article intentionally assumes that a facility does not have significant harmonic currents present. However, some caution must be taken when applying capacitors in a circuit where harmonics are present (true power factor).

Although capacitors themselves do not generate harmonics, problems arise when capacitors for power factor correction improvement are applied to circuits with nonlinear loads that interject harmonic currents. Those capacitors may lower the resonant frequency of that circuit enough to create a resonant condition. Resonance is a special condition in which the inductive reactance is equal to the capacitive reactance. As resonance is approached, the magnitude of harmonic current in the system and capacitor becomes much larger than the harmonic current generated by the nonlinear load. The current may be high enough to blow capacitor fuses, create other "nuisance" problems, or develop into a catastrophic event. A solution to this problem is to detune the circuit by changing the point where the capacitors are connected to the circuit, changing the amount of applied capacitance, or installing passive filter reactors to a capacitor bank, which obviously increases its cost. Use of an active harmonic filter may be another solution.

Capacitor bank considerations and associated costs:

The selection of the type of capacitor banks and their location has an impact on the cost of capacitor banks. More difficult than determining the total capacitance required is deciding where the capacitance should be located. There are several factors to consider, including:

Should one large capacitor bank be used, or is it better to add small capacitors at individual loads?

Should fixed or automatically switched capacitors be employed?

In general, since capacitors act as a kVAR generator, the most efficient place to install them is directly at an inductive load for which the power factor is being improved.

Fixed capacitor location schemes include:

This will generally improve losses, although it is not an optimal solution.Distributing the capacitors using the motor sizes and the NEMA tables as a guide. This solution does not reflect the need for more released capacity, if this is a goal. Capacitors sized for small loads are often proportionally much more expensive than larger fixed capacitors, primarily because of installation costs.

Capacitor switching options include:

Switching a few of the capacitors with larger motors is an option. The capacitors may be physically installed either directly connected to the motor or through a contactor on the motor control center that is tied in with the motor control. If the motors are large enough to use capacitors of the same size as were being considered for the fixed capacitor scheme, little additional cost is incurred for installing them on the motors. Where the economy is lost is when the capacitors are placed on several small motors. There is relatively little difference in installation costs for large and small 480-V units.

The second switching option is to consider an automatic power factor controller installed in the capacitor bank. This will switch large capacitor banks in small steps (25 through 50 is common) to follow the load. Automatic power factor capacitor banks should be installed at the motor control center rather than on the main bus, if optimal distribution loss is a goal. The economics of purchasing, installing, protecting, and controlling single large automatically switched capacitor banks can tilt the decision toward a main bus location, especially if the primary goal is to avoid power factor penalties.

Reactors can be added to fixed or automatic power factor capacitor banks to prevent the risk of the harmful effects of harmonics (detuned filters).

Power quality:

Transients:

- ✓ Impulsive Transients
- ✓ Oscillatory Transients

Short Duration Variation:

- ✓ Voltage Sags or Dips
- ✓ Voltage Swells
- ✓ Interruptions
- ✓ Voltage Magnitude Step

Long Duration Variation:

- ✓ Undervoltages
- ✓ Overvoltages
- ✓ Interruptions

What is power quality?

Power quality is simply the interaction of electrical power with electrical equipment. If electrical equipment operates correctly and reliably without being damaged or stressed, we would say that the electrical power is of good quality. On the other hand, if the electrical equipment malfunctions, is unreliable, or is damaged during normal usage, we would suspect that the power quality is poor.

As a general statement, any deviation from normal of a voltage source (either DC or AC) can be classified as a power quality issue. Power quality issues can be very high-speed events such as voltage impulses / transients, high frequency noise, waveshape faults, voltage swells and sags and total power loss. Each type of electrical equipment will be affected differently by power quality issues. By analyzing the electrical power and evaluating the equipment or load, we can determine if a power quality problem exists. See Power Quality events for a more detailed description of power quality problems.

We can verify the power quality by installing a special type of high-speed recording test equipment to monitor the electrical power. This type of test equipment will provide information used in evaluating if the electrical power is of sufficient quality to reliably operate the equipment. The process is similar to a doctor using a heart monitor to record the electrical signals for your heart. Monitoring will provide us with valuable data; however the data needs to be interpreted and applied to the type of equipment being powered. Let’s look at two examples of interpreting data for a USA location (other countries use different voltages but the same principal applies).

Power Quality Events:

Power quality problems have many names and descriptions. Surges, spikes, transients, blackouts, noise, are some common descriptions given, but what do they mean? This section delves into defining power quality issues and terminology.

Power quality issues can be divided into short duration, long duration, and continuous categories. The computer industry has developed a qualification standard to categorize power quality events. The most common standard is the CBEMA curve (Computer Business Equipment Manufacturing Association).

What can cause power quality problems?

Typical problems include grounding and bonding problems, code violations and internally generated power disturbances.

Other internal issues include powering different equipment from the same power source. Lets take an example of a laser printer and a personal computer. Most of us would not think twice about plugging the laser printer into the same power strip that runs the PC. We are more concerned about the software and communication compatibility than the power capability; however, some laser printers can generate neutral-ground voltage swells and line-neutral voltage sags every minute or so. The long term effect to the PC may be power supply failure. We have to be careful in how technology is installed and wired.

Most common Power Quality problems:

Voltage sag (or dip)

Description:

A decrease of the normal voltage level between 10 and 90% of the nominal rms voltage at the power frequency, for durations of 0,5 cycle to 1 minute.

Causes:

Faults on the transmission or distribution network (most of the times on parallel feeders). Faults in consumer‟ s installation. Connection of heavy loads and start-up of large motors.

Consequences:

Malfunction of information technology equipment, namely microprocessor-based control systems (PCs, PLCs, ASDs, etc) that may lead to a process stoppage. Tripping of contactors and electromechanical relays. Disconnection and loss of efficiency in electric rotating machines.

Energy conservation:

Energy conservation refers to efforts made to reduce energy consumption. Energy conservation can be achieved through increased efficient energy use, in conjunction with decreased energy consumption and/or reduced consumption from conventional energy sources

Energy being an important element of the infrastructure sector has to be ensured its availability on sustainable basis. On the other hand, the demand for energy is growing manifold and the energy sources are becoming scarce and costlier. Among the various strategies to be evolved for meeting energy demand, efficient use of energy and its conservation emerges out to be the least cost option in any given strategies, apart from being environmentally benign.

The steps to create sustainable energy system begin with the wise use of resources; energy efficiency is the mantra that leads to sustainable energy management.

Energy Demand and Supply:

On the energy demand and supply side, India is facing severe shortages. 70% of the total petroleum product demand is being met by imports, imposing a heavy burden on foreign exchange. Country is also facing Peak power and average energy shortages of 12% and 7% respectively. To provide power for all, additional capacity of 100,000 MW would be needed by 2012, requiring approximately Rs.8000 billion investment. Further, the per capita energy consumption in India is too low as compared to developed countries, which is just 4% of USA and 20% of the world average. The per capita consumption is targeted to grow to about 1000 kWh per year by 2012 , thus imposing extra demand on power system.

Importance of Energy Conservation

In a nario where India tries to accelerate its development process and cope with increasing energy demands, conservation and energy efficiency measures are to play a central role in our energy policy. A national movement for energy conservation can significantly reduce the need for fresh investment in energy supply systems in coming years. It is imperative that all-out efforts are made to realize this potential. Energy conservation is an objective to which all the citizen in the country can contribute. Whether a household or a factory, a small shop or a large commercial building, a farmer or a office worker, every user and producer of energy can and must make this effort for his own benefit, as well as that of the nation.

Energy audit methodology

- ✓ The methodology adopted for this audit was
- ✓ Formation of audit groups for specific areas and end use
- ✓ Visual inspection and data collection
- ✓ Observations on the general condition of the facility and equipment and quantification
- ✓ Identification / verification of energy consumption and other parameters by measurements
- ✓ Detailed calculations, analyses and assumptions
- ✓ Validation
- ✓ Potential energy saving opportunities
- ✓ Implementation

An energy audit is a preliminary activity towards instituting energy efficiency programs in an establishment. It consists of activities that seek to identify conservation opportunities preliminary to the development of an energy savings program.

The Role of an Energy Audit

To institute the correct energy efficiency programs, you have to know first which areas in your establishment unnecessarily consume too much energy, e.g.which is the most cost-effective to improve. An energy audit identifies where energy is being consumed and assesses energy saving opportunities - so you get to save money where it counts the most.

Contents of an Audit

An energy audit seeks to document things that are sometimes ignored in the plant, such as the energy being used on site per year, which processes use the energy,and the opportunities for savings. In so doing, it assesses the effectiveness of management structure for controlling energy use and implementing changes. The energy audit action plan lists the steps and sets the preliminary budget for the energy management program.

1. Analysis of energy use

Identifying where energy is used is useful because it identifies which areas the audit should focus on and raises awareness of energy use and cost. The results of the analysis can be used in the review of management structures and procedures for controlling energy use.

2. Identification of energy projects

Opportunities for energy savings can range from the simplest, such as lighting retrofits, to the most complex such as the installation of a cogeneration plant. The important thing to remember is to focus on major energy users and areas. Always apply the 80/20 rule, focus on opportunities that provide 80% of the saving but require 20% input. After the preliminary identification of opportunities, spend more time on those which have shorter payback periods.

3. Cost benefit analysis

The identified energy conservation opportunities should be analyzed in terms of the costs of implementing the project versus the benefits that can be gained. If you want to, say, install a heat plate exchanger to recover waste heat, you need to calculate the total cost of installation and compare that with the savings you will derive from recovering waste heat. It makes sense to go on with the project if there is a net positive benefit from the project.

4. Action plan to set implementation priority

After passing the cost benefit test, an action plan should be developed to ensure that the opportunities identified are implemented. The action plan should include all the major steps for implementing the opportunity as well as the people responsible.Furthermore, there should be a plan for monitoring the results.

UNIT-3
ILLUMINATION

Introduction:

Light by definition connotes Electromagnetic radiation that has a wavelength in the range from about 4,000 (violet) to about 7,700 (red) angstroms and may be perceived by the normal unaided human eye. In fact in the prehistoric days, all human activities were coordinated with Sunrise and Sunset. Today, in principle activities are carried out round the clock. All this is made possible because of Artificial Lighting systems. The lighting systems comprise of a source employing any physical phenomenon among.

Incandence, Electrolumnience or Flourence. Some control scheme and a Luminaire. In fact all this has lead to a class of professionals called Lighting Engineers or Illumination Engineers. Unlike other group of professionals they need to be adept at not only at exact sciences of Maths, Physics, Chemistry; but be wary of Physiology and Psychology of users (like a medical professional); have good aesthetic sense and economically utilize resources.Efficacy of these systems is talked in terms of Illuminance per Watt of energy consumed. Efforts are on to reduce energy conmsumption yet have efficient Illumination to enhance productivity. Need less to mention that all these sources employ electrical energy.Trend these days is to employ, modern electronic controls together with energy efficient lamps.These aspects are borne in mind, right from the planning stage of a building. As electrical energy is being used for the purpose, it becomes important for Illuminating Engineer to come up with an integrated system for the complete electrical system of a building.

Importance of lighting:

Humans depend on Light for all activities. Light is a natural phenomenon, very vital for existence, which is taken for granted. In fact, Life involves day night cycles beginning with sunrise and ending with sunset. Pre-historic man had activities limited only to day time. Artificial light enables extended activity period employing in a planned optimized manner, minimizing the resources.

Vision is the most important sense accounting for 80% information acquisition for humans. Information may be acquired through sun/moon light (direct/ reflected) or by using artificial light (closest to natural light). Before we go any further, it is worth looking at Teichmuller's definition for lighting. "We say the lighting is good, when our eyes can clearly and pleasantly perceive the things around us". Therefore Artificial light should be Functional and pleasant both physiologically and psychologically. This is often achieved employing multiple sources. It must be borne in mind that the sources should be economic and energy efficient. As all of us are aware, all sources today employ electrical energy.

Electrical energy is supplied as a.c. (alternating current) or d.c. (direct current). Usually electric power supply is a.c. in nature, either single phase or three phases. It must be borne that close circuit is a must for current flow. As it is well known losses exist in all electrical circuits or lines.

Properties of good lighting scheme:

1. Incandence

Thermo luminence is by definition radiation at high temperature. The sources employing this process are Incandent Lamp, Gas Lamp, (flames and in oil Lamps and wax candles). They lead to a continuous spectrum of radiation.

2. Luminence:

Luminence Electro luminence by definition Chemical or Electrical Action on gases or vapour radiation. Here color of radiation depends on the material employed. Usually this process leads to Line or Band Spectrum.

3. Fluorence:

Fluorence is a process in which radiation is absorbed at one wavelength and radiated at another wavelength eg: UV impinging on Uranium – Fluorent oils. This re radiation makes the light radiated visible.

4. Phosphorence:

Phosphorence is a process when energy is absorbed at some time and radiated later as glow. Examples of this process are luminous paints that contain calcium sulfide that lead to Phosphorence**.** They produce light Radiation after exposure to light.In practice good efficient lighting is obtained by combining Luminence and Fluorence. Fluorent lamp is Luminent source of low luminous value activating Fluorent surfaces which lead to visible radiation. Here intensity depends on gas or vapor involved and phosphor material. However, the temperatures o f t h e m a t e r i a l p l a y a role in radiation.

Lumen

The lumen (symbolized lm) is the International Unit of luminous flux. It is defined in terms of candela steradians (cd multiplied by sr). One lumen is the amount of light emitted in a solid angle of 1 sr, from a source that radiates to an equal extent in all directions, and whose intensity is 1 cd.

Luminous intensity

Luminous intensity is an expression of the amount of light power emanating from a point source within a solid angle of one steradian.

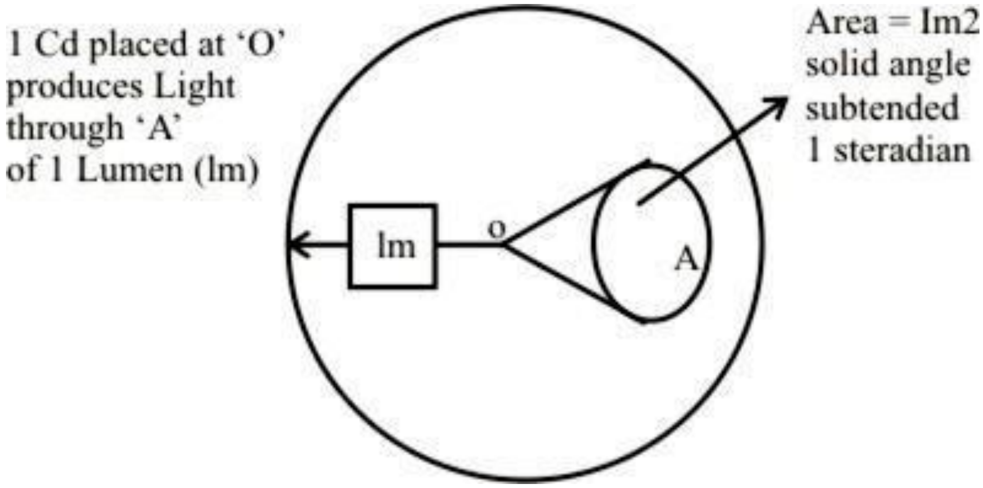
Laws of illumination:

The original standard of light was Wax Candle, which is highly unreliable. It was replaced by a Vaporized Pentane Lamp. This is equal to10 original Candles. In the year 1909, Incandent Lamp was taken as standard by comparison with a Pentane Lamp. Thing to be kept in mind is Primary Standard should be reproducible.It was in1948, Luminous Intensity; based on Luminance (objective brightness) of a small aperture due to Light from a Radiator maintained at1773°c i.e. Solidification temperature of platinum was adopted as Standard. It consists of:

1. Radiator – Fused Thoria – Thorium Oxide. 45mm long internal dia of 2.5mm. Packed with Fused Thoria Powder at the bottom.
2. Supported Vertically Pure Platinum in a Fused thoria crucible with a small aperture of 1.5mm in a large refractory container.
3. Platinum melted by a High Frequency Eddy current.Luminance = 589000 Candles /m2 ≈600 000 units.

Transparent:

Common unit of light intensity is candela. It is Luminous intensity in the Perpendicular direction of a surface, 1 / 600,000 of a black body at temperature of solidification or Freezing of Platinum under Standard Atmospheric pressure. It is abbreviated as Cd. It is indicative of Light Radiating Capacity of a source of Lamp.



Consider a transparent sphere of radius 1m shown in Fig. If we place a 1 Cd source at the centre then light flux coming out through an area of $1m^2$ over 1 steradian solid angle will be 1 lumen.

Thus Luminous Intensity over 1 Str. by 1, Cd, we call it 1 lumen ≈ 1 lm. Basic unit of Light Flux.

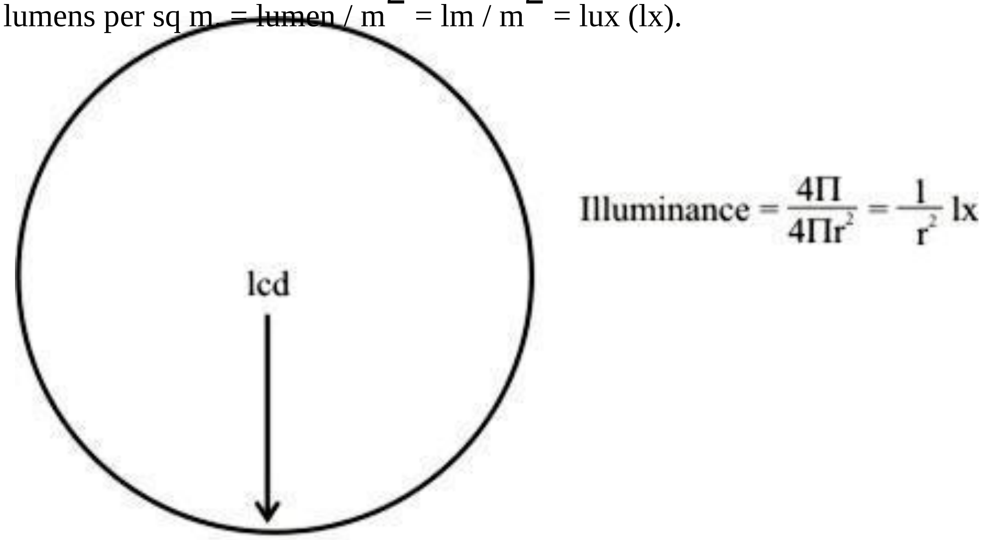
∴ Total Flux = 4 π lumens, out of the sphere in Fig.

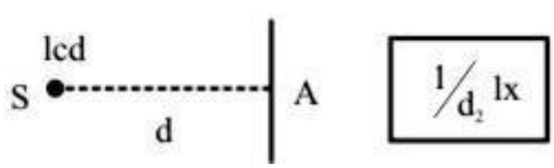
If the Solid Angle be dω and Luminous Intensity I Cd at the center then Luminous flux in dω =dφ = I dω lm.

Yet another important unit is MSLI. It means Mean Spherical Luminous Intensity. Average value of Luminous Intensity in all directions. Therefore for the case in Fig

φ = I 4πlumens

Now we define Luminous intensity on a surface. It is known as Illuminance. It is Luminous Flux per unit area or lumens per sq m. = ~~lumen~~ / m^2 = lm / m^2 = lux (lx).





Frechner's law:

Weber in 1830 found that I – Stimulus (Intensity) produces dI – Least perceptible increment affecting sense organs. Then the ratio

dI/i= Constant Under fixed –

1) Fatigue
2) Attention and
3) Expectation.

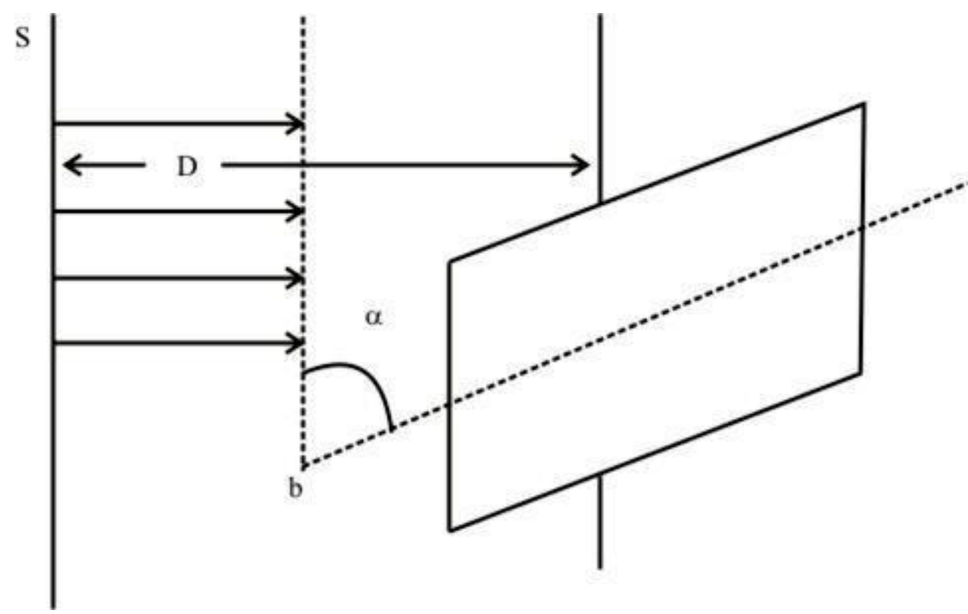
Thus we have sensitivity given by the equation

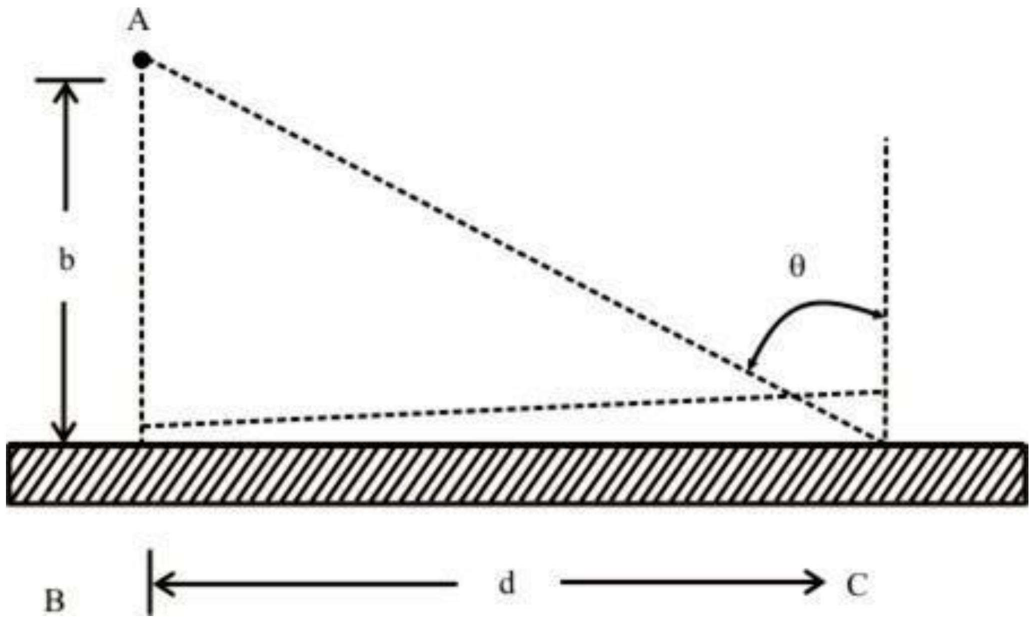
Here I0 is the threshold intensity. This is known as Frechner's Law. The same percentage change in stimulus Calculated from the least amount perceptible. Gives same change in sensation. Sensations produced by optic nerves have logarithmic dependence or relationship to Light Radiation producing the sensation.Intensity of Illumination produced by a point source varies inversely as square of the distance from the source. It is given by the equation and as shown in Fig E=I/D

Lambert's Cosine Law of Incidence

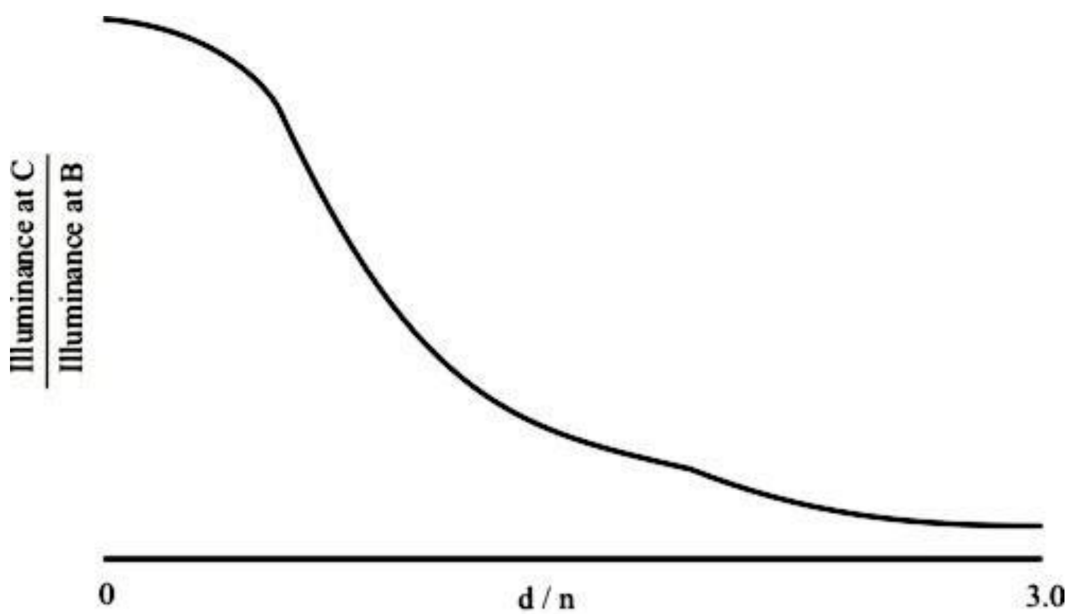
$$E = \frac{I \cos}{D^2}$$

This – tells us the variation of Illuminance on arbitrary surface inclined at an angle of α. As shown in Fig





Above Fig.shows a lamp placed at A, the 5m above the floor. For this scheme below Fig shows It variation of Illuminance on the floor. is well known that Illuminance is maximum under the lamp at 'B'.



60 - 75° to the Vertical

$$\text{Illuminance at B} = \frac{\text{LI in direction AB}}{b^2}$$

$$\text{Illuminance at C} = \frac{\text{LI in direction AC}}{AC^2}$$

$$= \frac{\text{LI in direction AB} \times \text{Cos}\theta}{(b^2 + d^2)}$$

- Illuminance at C = Illuminance at Bx Cos3θ

Next is to measure the candle power of the lamp. Typical measurement can be done using a photometric bench shown in Fig. 7 where IS represents standard lamp. IX represents test lamp. There is a screen at the centre called photometer head, adjusted for equal brightness on either side. Applying inverse law one can arrive at the value of IX.

This lesson introduced the primary standard and other terminology related to measurement of light flux.

Photometry:
Primary Standard was defined in an earlier lecture based on the brightness of a body (i.e. black body) maintained at Freezing Temperature of platinum. Unit of Luminous Intensity abbreviated as is candela cd (z). Light Flux hence emanating from a point source in all directions is Illuminance - ¼ π lumens and is termed msli is the light flux incident on a task surface in lumens
per unit area and is called lux. Comparison with a standard. Normally Primary standards are kept in standards Laboratories. Usually Incandent Lamp Compared with a Primary standard is used as a Laboratory Standard. The test source / lamp is compared With the Laboratory Standard. However, Incandent Lamp not suitable beyond 50 – 100 hours Standardization of Lamp is by voltage rating Current rating and wattage.

These measurements comprise photometry. They employ a Photometric Bench with a photometric head which is an opaque screen. These measurements involve compassing the test lamp with standard lamp

a. By varying the position of comparison lamp (standard Lamp) Is b. By varying the position of the test lamp IT
c. By varying the position of the screen

Measurement is complete when the bench is balanced. It is balanced when two sides of the screen are equally bright [in a Dark Room] as shown in Fig.1
Photometric Bench:

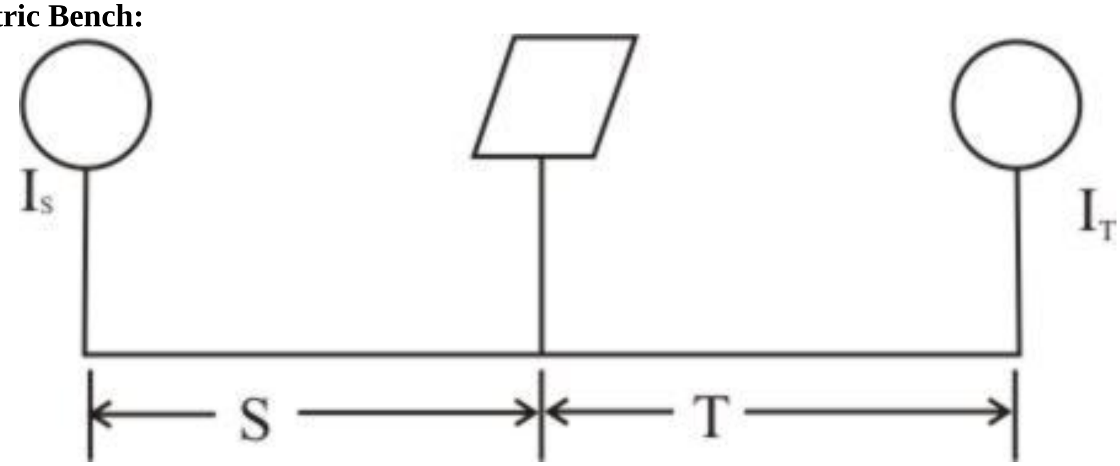


Fig. 1 Photometric Bench

Measurements may be made on Illumination meter or Lux meter also in this instead of the screen adjust the meter to get the same reading on photometric bench. Fig.2. shows a method where distance is varied to get the same reading on the meter.

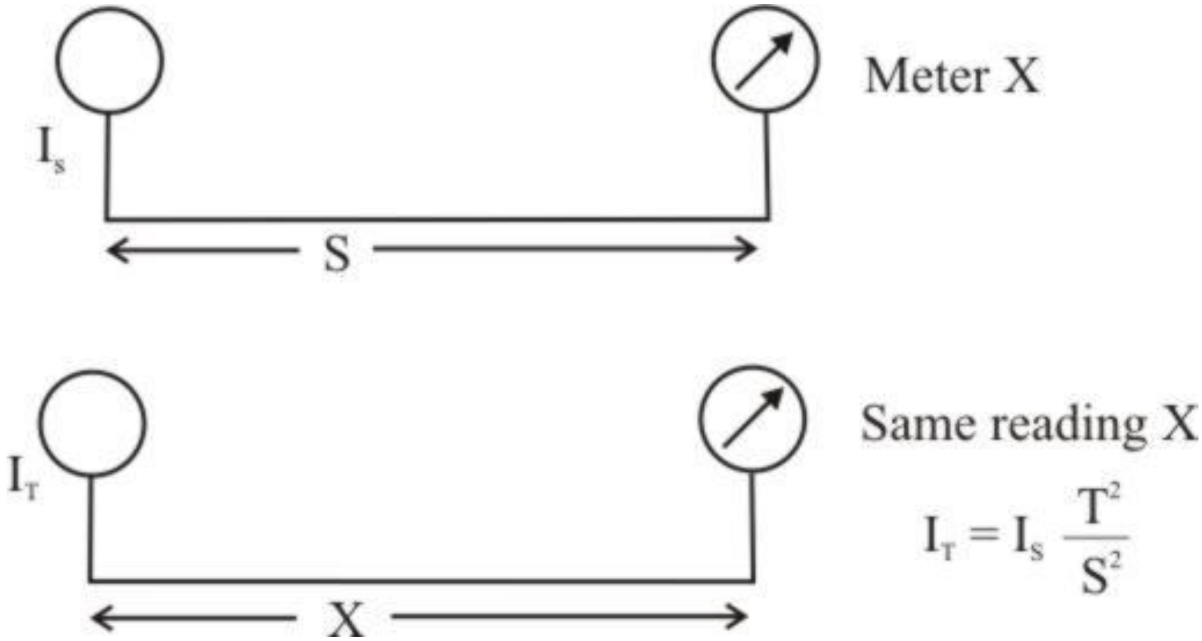


Fig. 2 Use of Lux meter on Photometric Bench

Alternatively, the distance on the bench may be kept constant and readings on the meter are noted.

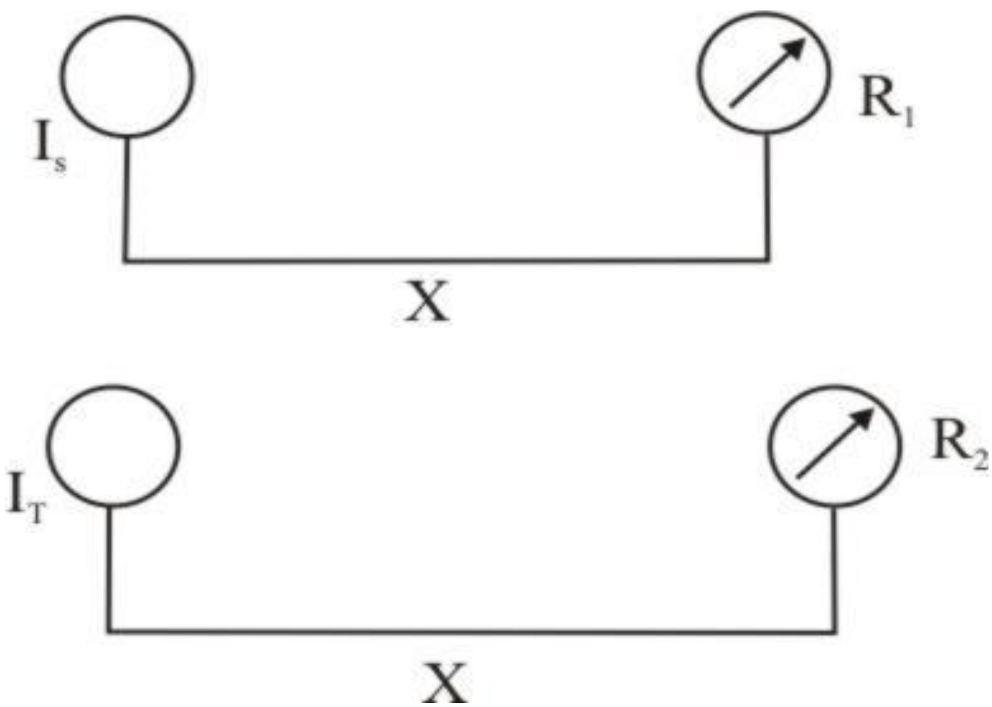


Fig. 3 Photometric Bench with Lux meter at a Constant Distance

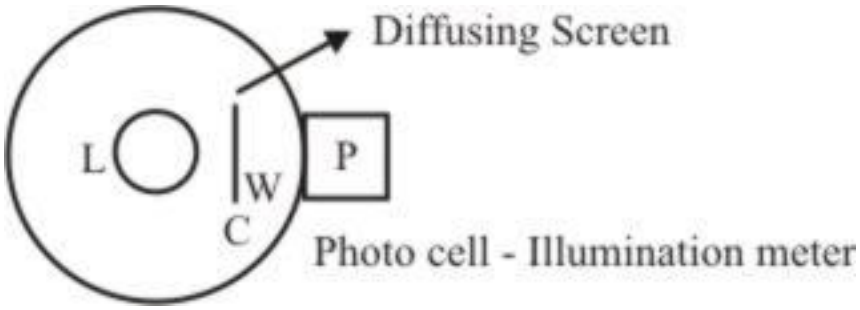


Fig. 4 Integrating Photometer

Fig 4 shows a typical photo meter. It has a standard point source 'L' of Light at the centre of a opaque sphere. It has an opening W where a photo cell is placed that receives diffused light from the source. Window 'W' is shielded by diffusing screen 'C' from direct light. Reading on the micrometer is first taken with a standard Lamp and later with the test Lamp.

Fig. 5 shows the photocell employed in a photometer. In a photocell sensitive element 'S' is selenium coated in the form of a thin layer on a steel plate P. This is in turn covered with a thin layer of Metal 'M' on which is a collection ring R.

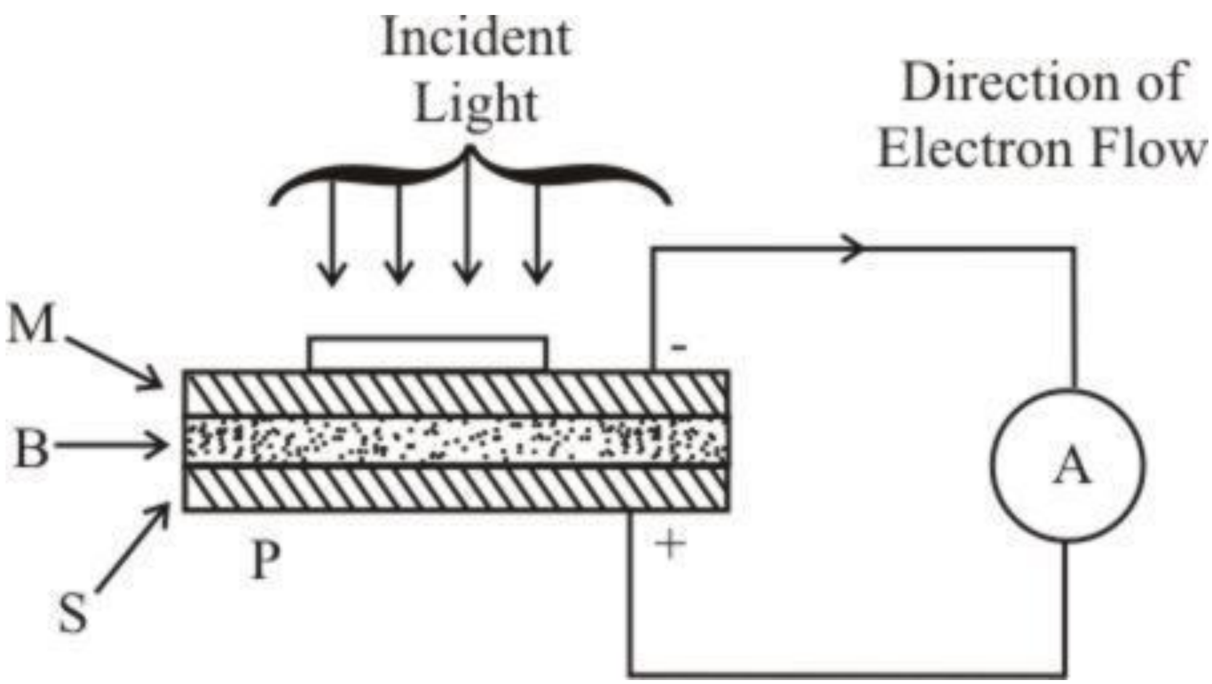


Fig. 5 Photovoltaic cell

Sensitive element is a semi-conductor that releases electrons upon exposure to light. Selenium and Cuprous oxide are most suitable semi-conductor materials. Steel Plate 'P' coated with thin layer of Selenium at 200°c and annealed at 80°c Producing crystalline form. It is in turn coated by a thin transparent film of metal 'M' with a collection ring 'R' of metal.

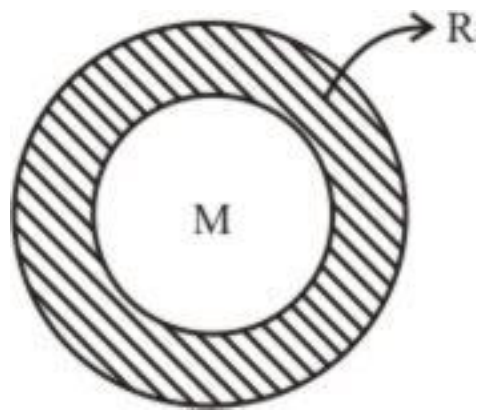


Fig. 6 Top view of a photo cell

B is the barrier Layer Upon exposure to light – light enters through 'M' releases electrons from metallic Selenium. They cross barrier 'B' to 'M' and are collected through 'R' and P Current indicated by (A) is proportional to Illuminance. Often (A) is a micro ammeter calibrated in lm.

The next aspect of photometry is to look at the luminance curves of the Lamps. Here comes the role of Luminaries. Luminaries primarily provide the physical support to the Lamps. They may be directing, globes, reflecting or refracting. They could be supported on the walls using wall branects. They may be portable units on pole mounted in case of street Light. In all cares we need light distribution curves. Light distribution curves are curves giving Variation of Luminous intensity with angle of emission in a Horizontal plane i.e. Polar angle Azimuth or Vertical plane, passing though centre.

Fig 7 shows a typical Polar Luminance distribution curve of a point source of Light. From a Polar Curve in order to arrive at msli of the lamp a Rousseau diagram is constructed. Fig 8 shows such a construction.

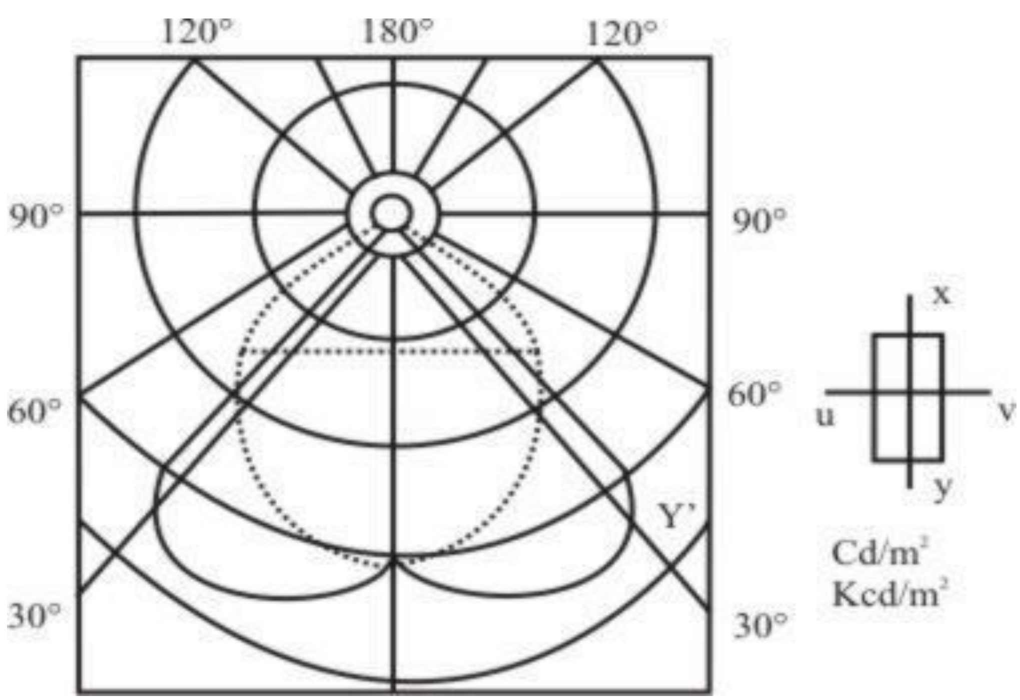


Fig.7 A typical Polar Luminance distribution diagram

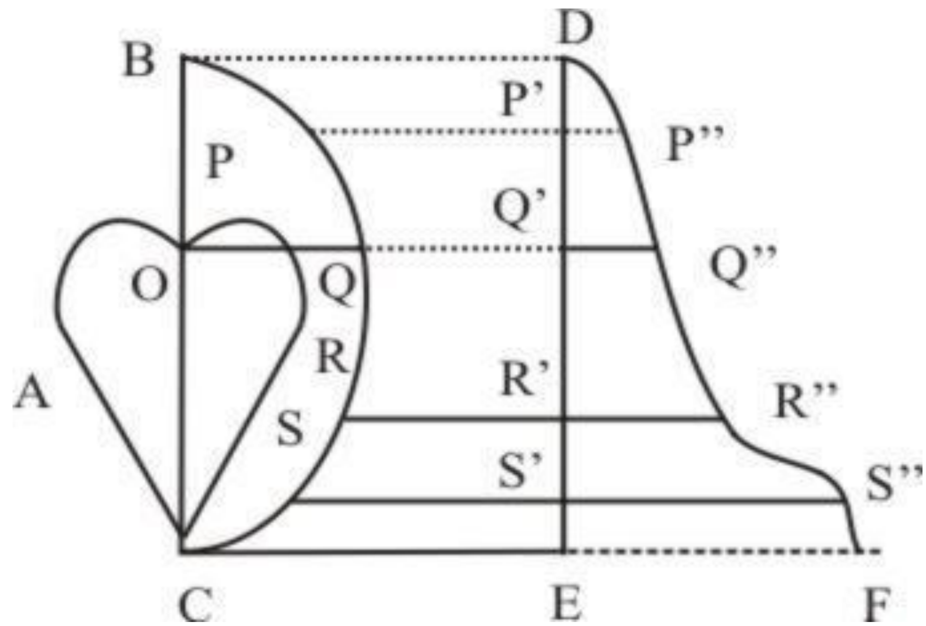


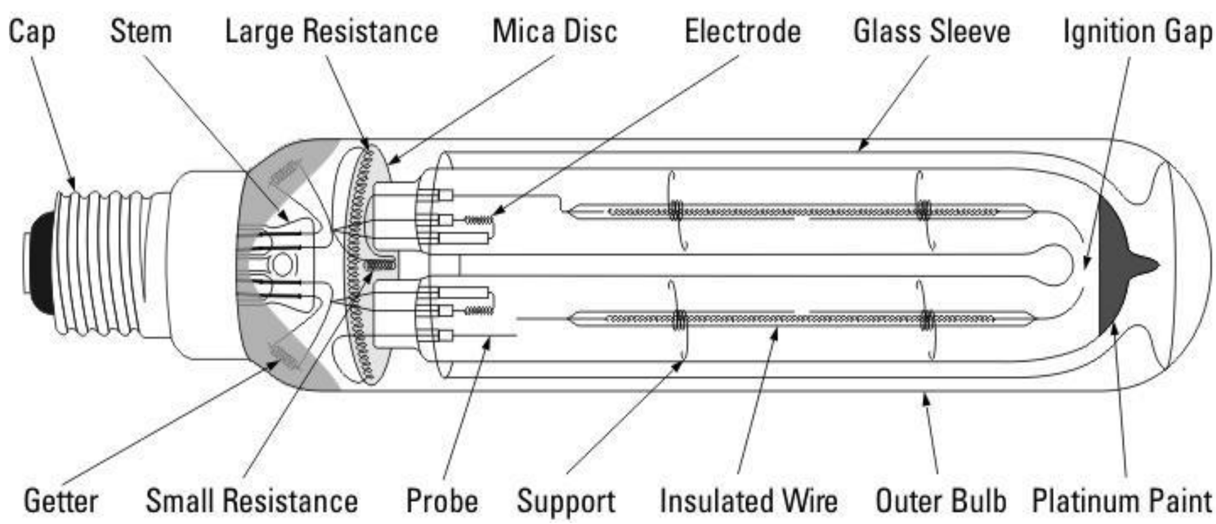
Fig. 8 Rousseau Diagram

Consider the Polar curve A for the typical lamp with O as centre of the Lamp Draw a semicircle of convenient radius OB = OC Insert no. of radii. From the top of there radial segments. From the tip of the radial segments draw horizontal lines extended to cut the vertical line to scale depending on length of Radic. Then the average width of the curve DP “Q” R “S” F is msli.

Types of lamps:

"Arc lamp" or "arc light" is the general term for a class of lamps that produce light by an electric arc (also called a voltaic arc). The lamp consists of two electrodes, first made from carbon but typically made today of tungsten, which are separated by a gas. The type of lamp is often named by the gas contained in the bulb; including neon, argon, xenon, krypton, sodium, metal halide, and mercury, or by the type of electrode as in carbon-arc lamps. The common fluorent lamp is actually a low-pressure mercury arc lamp

High Pressure Mercury Vapour Lamp:

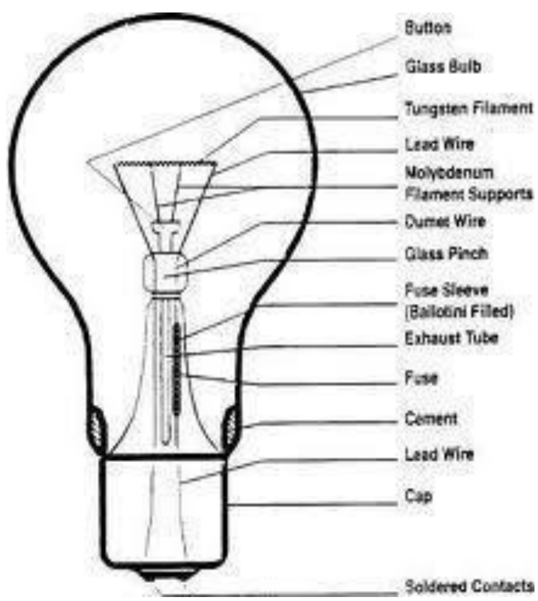


The mercury vapour lamp in construction is similar to sodium vapour lamp. It gives greenish blue colour light, which causes colour distortion. The efficiency is about 30-40 lumens per watt. These lamps (MA type) are manufactured in 250 and 400 W ratings for use on 200-250 Vac supply. Lamps of this type are used for general industrial lighting, railway yards, ports, work areas; shopping centers etc where greenish-blue colour ligh is not objectionable. Another type, which is manufactured in 300 and 500 W ratings for use on ac as well as dc supply mains is MAT type. This is similar to MA type except that it does not use choke as ballast. Lower wattage lamps, such as 80 and 125 W, are manufactured in a different design and using high vapour pressure of about 5-10 atmospheres. These are known as MB type lamps.

Incandent lamp:

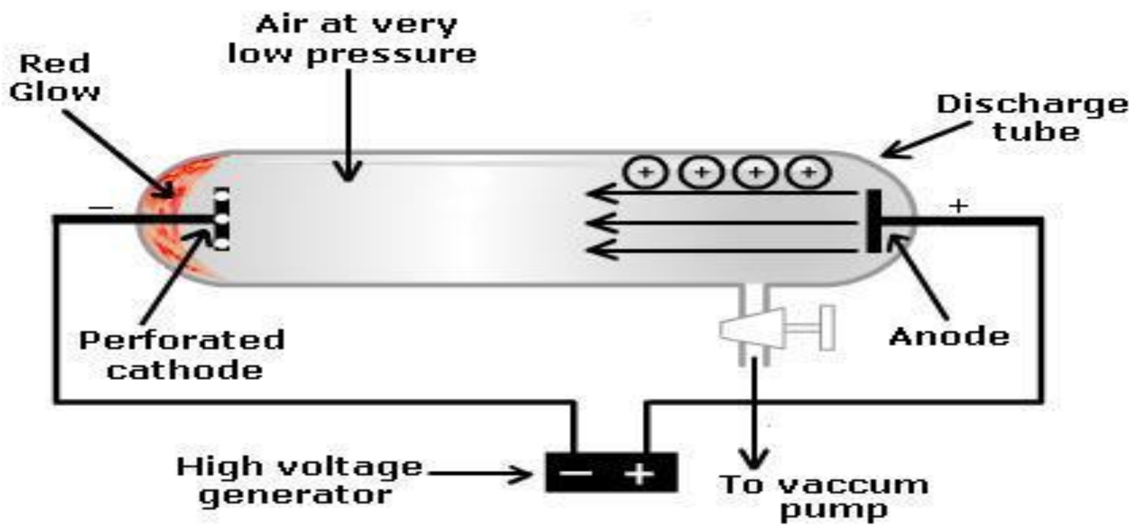
The incandent light bulb, incandent lamp or incandent light globe produces light by heating a metal filament wire to a high temperature until it glows. The hot filament is protected from oxidation in the air with a glass enclosure that is filled with inert gas or evacuated. In a halogen lamp, filament evaporation is prevented by a chemical process that redeposit’s metal vapor onto the filament, extending its life. The light bulb is supplied with electrical current by feed-through terminals or wires embedded in the glass. Most bulbs are used in a socket which provides mechanical support and electrical connections. Incandent bulbs are manufactured in a wide range of sizes, light output, and voltage ratings, from 1.5 volts to about 300 volts. They require no external regulating equipment, have low manufacturing costs, and work equally well on either alternating current or direct current. As a result, the incandent lamp is widely used in household and commercial lighting, for portable lighting such as table lamps, car headlamps, and flashlights, and for decorative and advertising lighting.

Some applications of the incandent bulb use the heat generated by the filament, such as incubators, brooding boxes for poultry, heat lights for reptile tanks, infrared heating for industrial heating and drying processes, and the Easy-Bake Oven toy. This waste heat increases the energy required by a building's air conditioning system.



Gaseous discharge lamps:

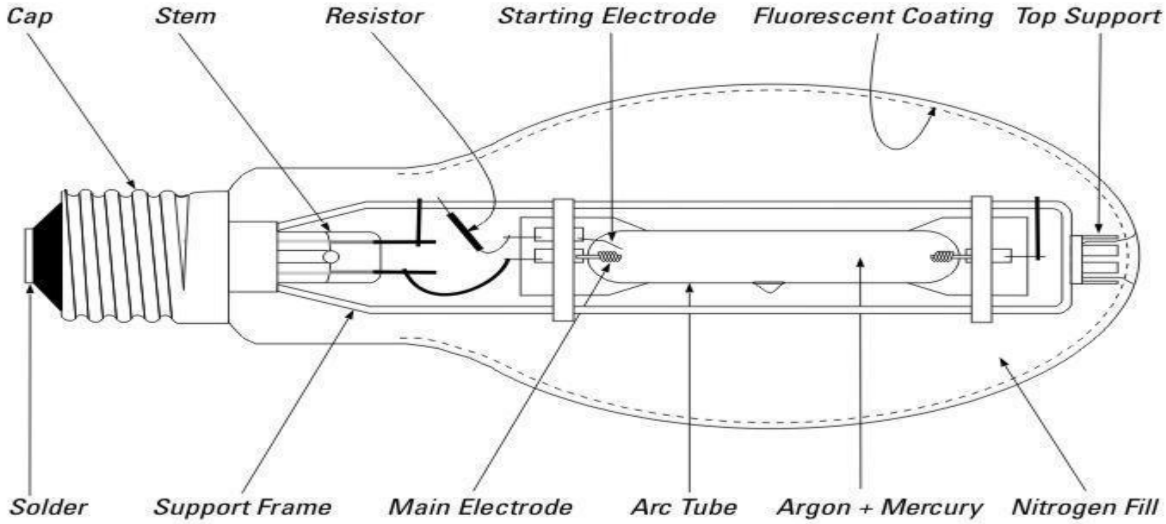
Gas-discharge lamps are a family of artificial light sources that generate light by sending an electrical discharge through an ionized gas, i.e. a plasma. The character of the gas discharge critically depends on the frequency or modulation of the current: see the entry on a frequency classification of plasmas. Typically, such lamps use a noble gas (argon, neon, krypton and xenon) or a mixture of these gases. Most lamps are filled with additional materials, like mercury, sodium and/or metal halides. In operation the gas is ionized and free electrons, accelerated by the electrical field in the tube, collide with gas and metal atoms. Some electrons in the atomic orbitals of these atoms are excited by these collisions to a higher energy state. When the excited atom falls back to a lower energy state, it emits a photon of a characteristic energy, resulting in infrared, visible light, or ultraviolet radiation. Some lamps convert the ultraviolet radiation to visible light with a fluorent coating on the inside of the lamp's glass surface. The fluorent lamp is perhaps the best known gas-discharge lamp.



Gas-discharge lamps offer long life and high efficiency, but are more complicated to manufacture, and they require auxiliary electronic equipment such as ballasts to control current flow through the gas. Due to their greater efficiency, gas-discharge lamps are replacing incandent lights in many lighting applications.

Sodium Vapour Lamp:

Principally sodium vapour lamp consists of a bulb containing a small amount of metallic sodium, neon gas and two sets of electrodes connected to a pin type base. The lamp operates at a temperature of about 300°C and in order to conserve the heat generated and assure the lamp operating at normal air temperatures the discharge envelope is enclosed in special vacuum envelope designed for this purpose. The efficiency of a sodium vapour lamp under practical conditions is about 40-50 lumens/watt. Such lamps are manufactured in 45, 60, 85 and 140 W ratings. The average life is about 3000 hours and is not affected by voltage variations. The major application of this type of lamp is for highway and general outdoor lighting where colour discrimination is not required, such as street lighting, parks, rail yards, storage yards etc.



Fluorent Lamp:

Employs transformation of UV radiation due to low pressure mercury vapor. Luminent Powder in tubular vapor Lamps Enhances brilliancy of light.Radiation from Low Pressure Mercury Vapor (which is in UV region) is impinged on Luminent Materials and re – radiated at longer wavelengths of visible spectrum. In a Glass Tube small drop of Mercury and small amount of Argon gas are placed for initiation of discharge. Pressure, voltage and current are so adjusted that 253.7 nm line is excited. This re-radiates at longer wavelength. Typically a 40W lamp requires 2-3g of phosphors. Maximum sensitivity is around 250 – 260 nm. Various types of Fluorent Lamps are:

1. Day Light Fluorent Lamps- Average Noon Day Light. 6500°k suitable where demands are not exacting
2. Standard white Light - 3500°k general Lighting.
3. 4500°k white Lamp – between std. white Light & Day Light Lamp.
4. Soft white Lamp – Pinker Light. 25% lower light output than Std. white Lamp suitable for Residential lighting and Restaurants.

Dimension and Voltage depend on Luminous Efficacy, Brightness, Lumen Output and Lumen Maintenance. Reliable Starting is achieved by having preheated cathodes / hot cathode. Half the open circuit voltage should be used by the Lamp and the other half by the ballast. Lamp Voltage decides the arc length, bulb diameter and lamp current. Hot Cathode lamps operate at lower voltage < cold Cathode lamps. Typically cold cathodes have 70-100V drop at the cathode.

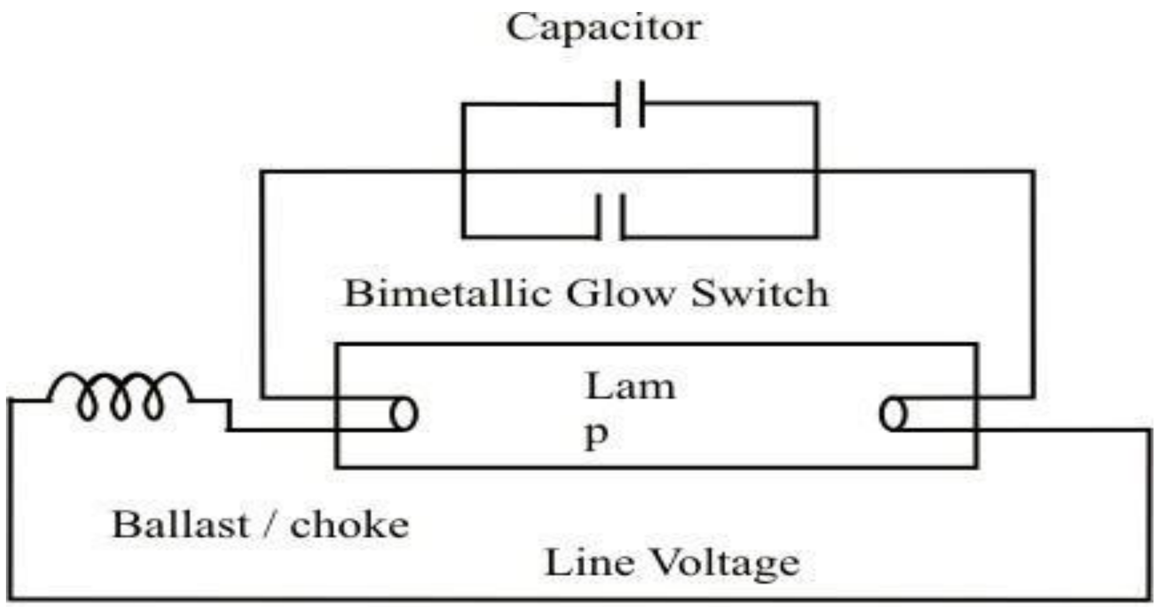


Fig. 1: Fluorescent Lamp

Lighting Calculations:

Inverse-square law

The skilled application of computerized point lighting calculations can optimize lighting levels in both the task and ambient domains in order to minimize energy consumption. The lighting professional should consider the use of point lighting calculations, both to design more energy-efficient spaces, and to create spaces with more drama and visual interest.

Point calculations are an exceptionally accurate way to compare general lighting systems. While the easier lumen method allows the comparison of average luminance, point calculations permit the comparison of uniformity of light on the work plane, the patterns of light produced on ceilings and walls, and task contrast rendering. More specifically, point calculations allow consideration of the effects listed below.

Effect on Room Surfaces. By evaluating the patterns of light on a wall caused by a row of compact fluorent down lights, an aesthetic evaluation can be made. Artwork locations may be selected or lighting may be designed to highlight artwork. It may also be possible to determine whether the pattern created on a wall will produce luminance extremes that will cause glare or reflections in VDT screens.
Indirect Lighting Effects on Ceiling. When they are too close to the ceiling, indirect lighting systems may create definite stripes or pools of light on the ceiling that are distracting and that may image in VDT screens. Careful ceiling luminance calculations can help identify the problem, and allow comparison of lighting products with various optical distributions and suspension lengths to reduce the effect. Gray-scale printouts or shaded VDT screen output of luminance make visual assessments possible.
Interior Task-Ambient Lighting. Point calculations should be used for any type of lighting design where the task locations and types are well known and are unlikely to move without a lighting redesign. They may also be used for lighting designs where tasks that move end up in predefined locations.

Cautions for Point Calculations. In the case where a task light is used, or where an indirect fixture is mounted within 12 inches of the ceiling, point calculations are not always appropriate. In general, if the luminaire is close to the surface where lighting patterns are to be evaluated, a near field situation exists. A shortcoming of the mathematics used in point calculations is that these near field calculations are comparatively inaccurate unless near field photometric data is available from the luminaire manufacturer, or the computer program is capable of adjusting the characteristics of the luminaries to improve the accuracy of the results. Otherwise, it may be more accurate to evaluate the light patterns from the task light or indirect fixture empirically.

The most common methods used for lighting calculations are:

(1) Watts per Square Meter Method. This is principally a „rule of thumb" method very handy for rough calculations or checking. It consists of making an allowance of watts/m^2 of area to be illuminated according to the illumination desired on the assumption of an average figure of overall efficiency of the system.

(2) Lumen or Light Flux Method. This method is applicable to those cases where the sources of light are such as to produce an approximate uniform illumination over the working plane or where an average value is required. Lumens received on the working plane may be determined from the relation.

Lumens received on the working plane = Number of lamps X wattage of each lamp X lamp efficiency (lumens/watt) X coefficient of utilization/depreciation factor.
(3) Point-To-Point or Inverse Square Law Method. This method is applicable where the illumination at a point due to one or more sources of light is required, the candle power of sources in the particular direction under consideration being known. This method is not much used because of its complicated and cumbersome applications.

Design of lighting system:
Direct lighting:

Lighting provided from a source without reflection from other surfaces. In day lighting, this means that the light has travelled on a straight path from the sky (or the sun) to the point of interest. In electrical lighting it usually describes an installation of ceiling mounted or suspended luminaires with mostly downward light distribution characteristics.

Indirect lighting:
Lighting provided by reflection usually from wall or ceiling surfaces. In day lighting, this means that the light coming from the sky or the sun is reflected on a surface of high reflectivity like a wall, a window sill or a special redirecting device. In electrical lighting the luminaries are suspended from the ceiling or wall mounted and distributes light mainly upwards so it gets reflected off the ceiling or the walls.

Types of Lighting:

One of the primary functions of a luminaries is to direct the light to where it is needed. The light distribution produced by luminaries is characterized by the Illuminating Engineering Society as follows:
Indirect Lighting= 90 to 100 percent of the light is directed to the ceilings and upper walls and is reflected to all parts of a room.

Semi-Direct Lighting=60 to 90 percent of the light is directed downward with the remainder directed upward.

Semi-indirect Lighting=60 to 90 percent of the light is directed upward with the remainder directed downward.

Highlighting Lighting= the beam projection distance and focusing ability characterize this luminaire
Industrial Luminaries:

Coming to industrial areas if in the Interior-up to 6m Fluorent Lamp with matt white reflector are employed. In High bays beyond 6m Discharge Lamps with Mirror Reflectors are employed. Luminaries in Hazardous Areas are specially designed. They are encapsulated in boxes made of steel or cast iron exterior housing to avoid any explosion, sturdy resisting pressure.

Categories of Explosive Areas:

In this respect explosives are as are categorized as
Zone 0 – Explosive all the time,
Zone 1 – Normally Explosive and
Zone 2 – Explosive Abnormally.

Here moisture & dust are taken care by Gasketted Luminnaires – Completely sealed eg: in a Shower or a Laundry. Emergency Lighting is required when normal lighting fails. Escape Lighting sufficient for evacuation typically 1 – 10 lx. Safety Lighting – 5% normal Lighting is provided in Potentially Hazardous areas. Standby power supply required for activation of vital implements. A permanent, separate, self supporting Power system which is reliable and mains rechargeable batteries in each Luminaries are provided

Non Permanent - Auto Switching - Emergency Generator - Battery Supply is also used.

Road Lighting:

Conventionally by they are arranged in a column, mounted on a wall or suspended by a span wire. Plane of Symmetry being in vertical plane perpendicular to the axis of the road along the road. **Catenary** – suspended from a catenary cable parallel to the axis of road. Plane of symmetry parallel to the axis of road. They employ Corrosion Resistant sturdy materials and are usually closed.

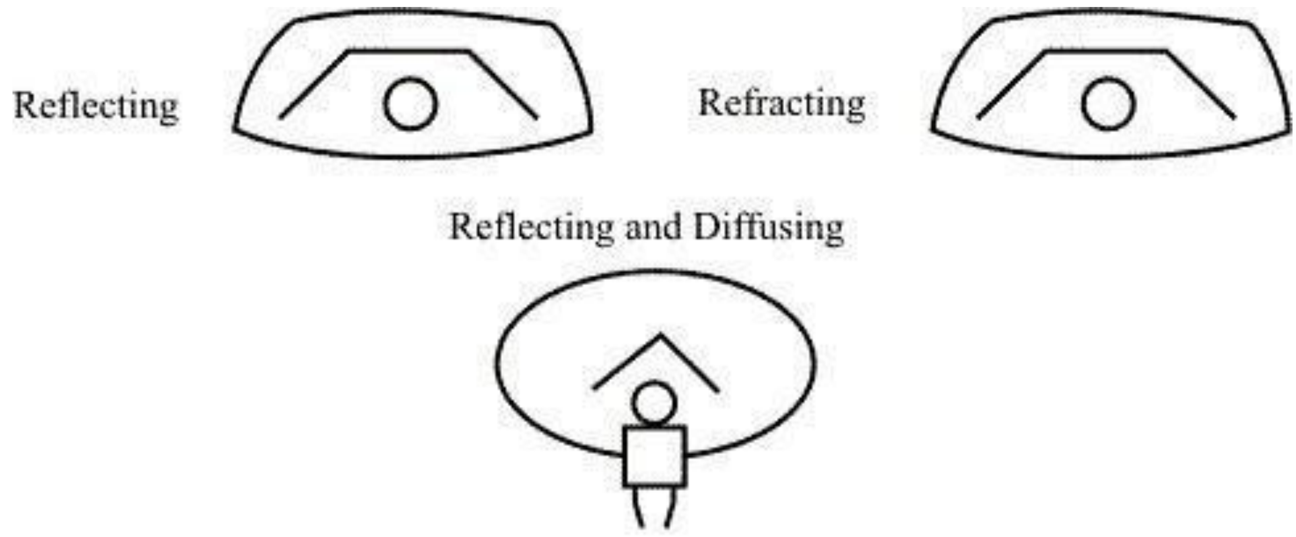


Figure 3: Typical Post top Lanterns

Flood Lights:

Rain Proof Lamp holder with wide / narrow beam Reflectors are used for flood light. They are usually High wattage Incandent Lamps, Halogen Lamps, High Pressure Mercury Vapor Lamp or Low / high Pressure Sodium Lamp.

Spot lights / down lights are usually used with Screens, Reflectors, Filters, Colored envelope and Closed Lamps.

Down lights are Spot lights when suspended.

As already brought out the components of an Illumination system are Lamp, the Radiation Source, Luminaire that directs and controls the light flux. Control Gear is the accessory that helps in controlling the requisite amount of flux on the work plane. Now we take a look at the accessories involved. First of these is Ballast. In a discharge lamp a series impedance to limit the current is required. If the current is allowed to increase there can be explosion of the lamp. This takes the form in a.c. as Inductance-w/o undue loss of power. This is called Ballast. It should have high power factor for economic use of the supply and should generate minimum harmonics. It should offer high impedance to audio frequencies. It should suppress-Electromagnetic interference (Radio interference-TV interference). It is essentially, a reactor of a wound coil on a magnetic core often called Choke and is in series with the lamp. Typical power factor is 0.5 Lag. Power factor is improved by having a capacitor connected across input lines.

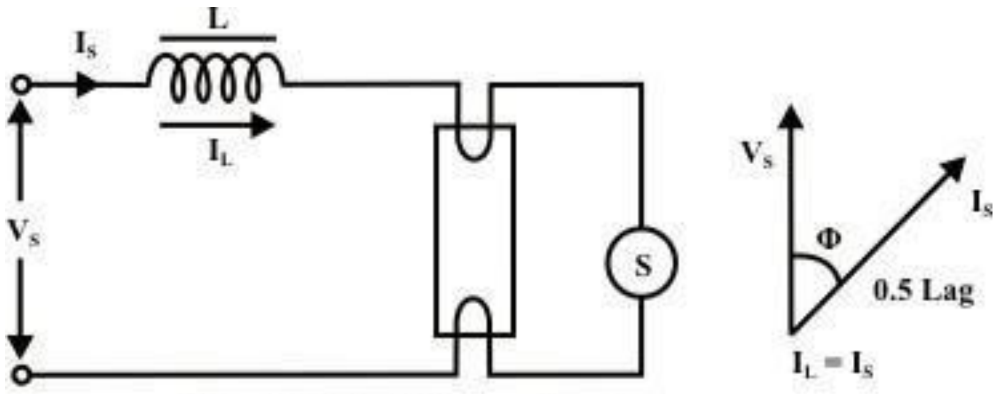


Fig. 1: Ballast Connection Diagram

Fig 1 shows the connection for a discharge lamp employing ballast formed by a reactor commonly known as choke. Fig 2 shows how the capacitor may be connected to improve the power factor. As may be seen the capacitor is placed in shunt. At times a lead circuit may result by placing a capacitor in series as shown in Fig 3. However, when a illumination system employing two lamps is used power factor may be improved by having one with a lead circuit and other with a lag circuit as shown in Fig. 4. Next important accessory is a starter that initiates the discharge in a discharge lamp. Starter is marked as 'S' in the Figs.1 to 4. Starter less circuit are shown in Fig 5. They employ pre-heated filament electrodes. The preheating obtained through a small portion of voltage tapped from the input source.

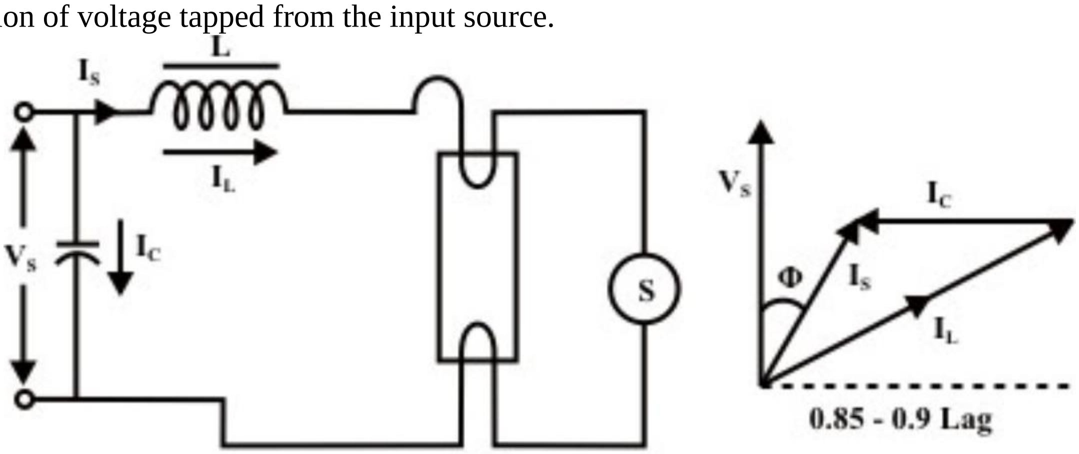


Fig. 2: Power Factor Improved by placing a Capacitor

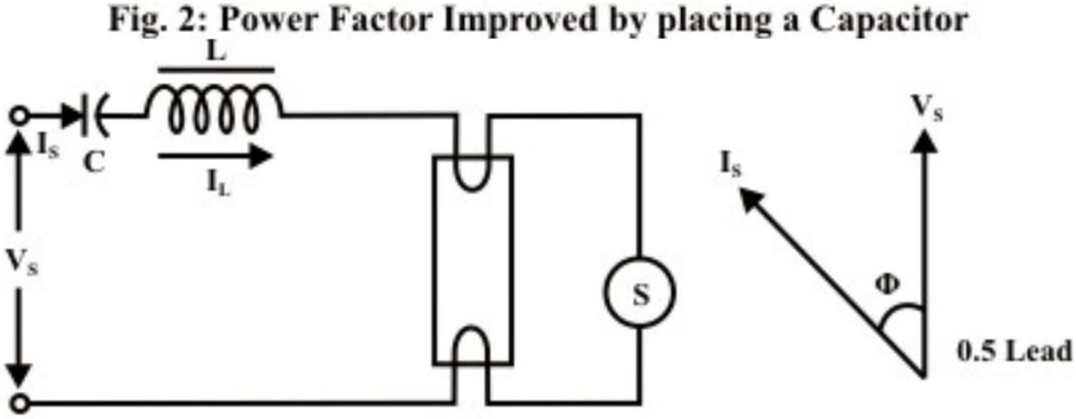


Fig. 3: Lead circuit

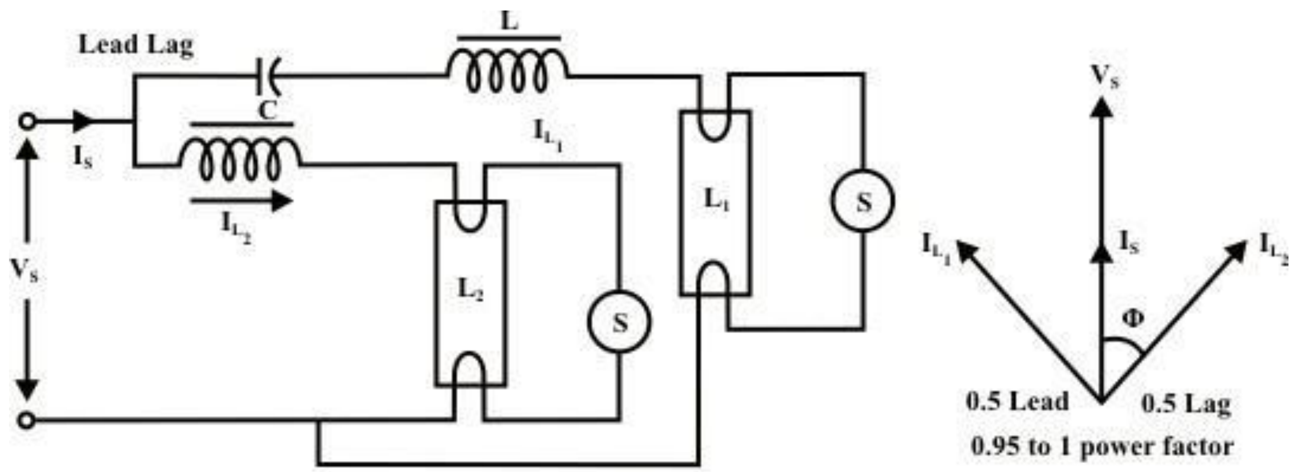


Fig. 4: Lead Lag Circuit

When discharge lamps are used on dc the ballast takes the form of a resistor together with associated power loss. These days they take the form of electronic ballast which converts dc to high frequency ac of around 20 kHZ.

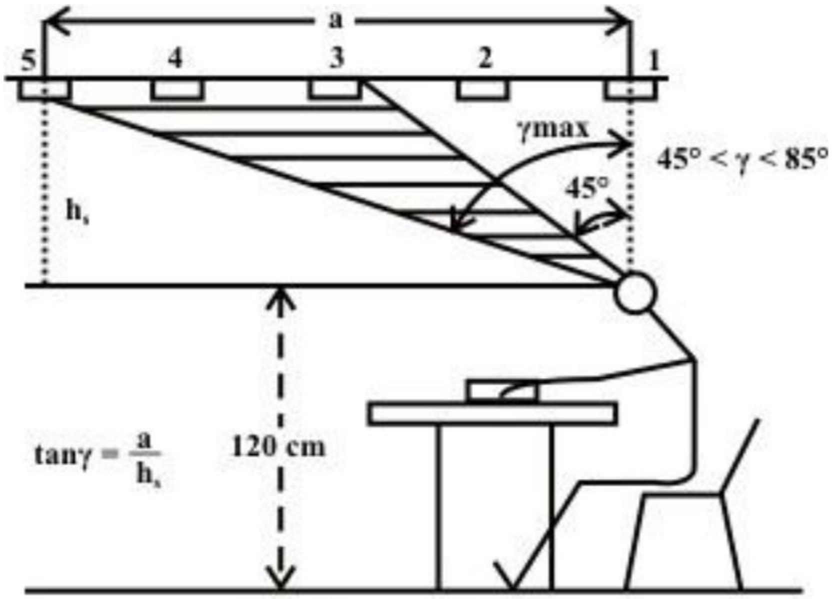
Except high pressure mercury lamp where V > VS (starting) all lamps need a starting device. At times, it is integral part of a lamp. Switch start employs bimetallic strip that opens upon heating. Starterless, rapid start or instant starts are useful for outdoor applications. Other forms of starters employed are three electrode devices called igniters.

Glare Evaluation:

Visual comfort system is most common evaluation in the USA/Canada. This is expressed as percentage of people considering an installation comfortable as viewed from one end. Glare tables list various proportions and layout of room for glare free lighting. Figure of merit is based on a source of 1000 lm.from a luminaire. If VCP ≈ 70% then the system is said to be glare free. British method employs Zone of luminaire with a classification for quality of light expressed as Glare index. Luminance limit system is adopted in Australia. Standard code for Luminaire base lamp. dep. on room dimensions, mounting height and a Empirical shielding angle Luminance curve system is employed in Europe.

Luminance limits for luminaires critical angles, γ are $45^\circ < \gamma < 85^\circ$. Quality class is expressed from A to E type is based on Luminaire orientation.

Type 1. Luminous sides when Luminous side plane> 30 mm



Radiant zone of Luminaire

Fig. 1: Illumination Zone of a typical Luminaire

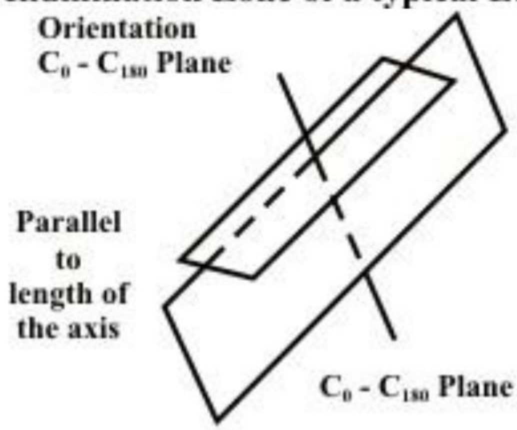


Fig. 2: Typical Type I Luminaire

General light is predominantly light coming downwards. Typically reflectance of 0.5 for walls /ceiling and 0.25 for furniture. How is Glare evaluated?

1. Determine luminance of the source between 45º - 85º
2. Determine the quality class and illuminance required.
3. Select the curve – class / level.
4. Determine. Max. Angle to be considered from length & height and plane of eye level & plane of luminaires. (Refer to Fig 1)
5. Horizontal limit based on" a / h", part of the line (or curve) to be ignored.
6. Compare luminance of one luminaire with selected part of the limiting curve.

Interior Lighting:

Interior Lighting is a complex problem depending on various factors such as

- Purpose intended service,

- Class of Interiors.
- Luminaire best suited,
- Color effect and
- Reflection from ceiling, walls, floors.

Good Lighting means intensity should be ample to see clearly and distinctly. The light distribution should be nearly uniform over a part of the room at least. It should be diffused that is soft and well diffused. Color depends on purpose and taste source but should approach daylight / yellow. Source location should be well above range of vision. To avoid glare intrinsic brightness is reduced by diffused glass ware and by remaining objects of secular reflection from range of vision. Shadows are a must for accentuating depth but should not too apparent abruptly or dense, they are not to be harsh and should toned down.

Standard practice is to have general lighting in all areas at a level comfortable to eye. It should eliminate dark shadows and avoid sharp contrast. In order to emphasize on parts that should be shown. Light sources located such that visual importance of object is kept in mind. Lamp may be concealed or counter lighted with a very low attention value to itself. Glare minimized by diffusing.

American Institute of Architects Recommends for Good Illumination.

1. General. Lighting – effectively illuminate all objects/areas with due regard to relative importance in the interior composition. Adequate for eye comfort throughout the room elimination of dark shadows and sharp contrasts – preserve soft shadows for roundness/relief – lighting emphasis on those parts that need first attention.

2. Light sources be subordinated in visual importance to the things intended to illuminate, except rarely when itself is a dominant decorative element. Unless – concealed/counter lighted, that they are not apparent they have extremely high attention value – dominate the scheme. If visible – so disposed – to attract eye to major feature of room than themselves.

3. Glare must be eliminated. Result of intense brightness in concentrated areas within the line of vision. Produced by excess brightness of visible light. reflection of bright lights from – Polished – low diffused surfaces - extreme contrast of light/shade
Employ – means of diffusing – at source or finish the room - with Diffusing/Absorbing materials rather than reflecting material.

4. Level of illumination to be adequate for the type of eye work. Local lighting to supplement general lighting adequate illumination – working at m/cs – desks – reading tables High level local lighting is always to be accompanied by general lighting to avoid eye strain and minimize controls. If glare is avoided there is no over illumination. Natural light limits are for outdoor 107600 lux and 1076 lux for indoor. Level should be adequate for eye task expected.

5. General lighting is to be related and controlled to suit the mood. While worship, meditation, introspection need low levels. Gaiety, mental activity, physical activity or intense activity needs high levels. Theaters, homes and restaurants may need levels varied according to mood. Shops level should be appropriate to woo customers through psychological reaction. Offices, factories and schools adequate illumination to work w/o eye strain**.**

6. Light source must suit interior in style, shape and finish in all architectural aspects.

Sports Lighting:

Lighting for sports facility looks for comfort of four user groups namely Players, Officials, Spectators and Media. Players and officials should see clearly in the play area to produce best possible results the object used in the game. Spectators should follow the performance of the players. In addition to play area surroundings also need to be illuminated. Lighting should be such that it enables safe entry and exit. With increasing crowd level safety becomes more and more important. Media include TV and film, for which lighting should provide lighting such that conditions are suitable for color picture quality as per CIE 83. This should be suitable for both general pictures as well as close up of players and spectators. Additionally, it should have provisions for emergency power supply to provide continuous transmission.

Criteria relevant for sports lighting are Horizontal Illuminance, Vertical Illuminance, Illuminance
Uniformity, Glare restrictions, Modeling & shadows and Color appearance & rendering

Energy efficiency lamps:

Horizontal Illuminance:

This becomes important as major part of view is illuminated playing area. Illuminance on the horizontal plane serves adaptation of the eye. It acts as a background, so adequate illuminance is important. For safe entry and exit adequate illumination is required in the circulation area also.

Vertical Illuminance:

Sufficient contrast across players' body is essential for the identification of the player. This is possible only if sufficient vertical illumination is there. This is characterized by both magnitude and direction. Players need adequate vertical illumination, from all directions. Spectators and Media need illumination only in defined directions. Generally, if horizontal illuminance is taken care, vertical illuminance levels become adequate. Usually vertical illuminance is specified or measured at a vertical height 1.5 m above the play area. Apart from player recognition and picture quality vertical illuminance should enable observation of movement of ball (or object moving in the sport concerned) above the playing field by both players and spectators. Spectator's stands are also part of the environment and must also have adequate vertical illuminance, more from the safety point of view.

Illuminance Uniformity:

Good illuminance is important in both the horizontal and vertical planes. If it be good it does away need for continuous adjustment of cameras. This is achieved by having Illuminance Uniformity.

Road Lighting:

Road lighting provides visual conditions for safe, quick and comfortable movement of Road users.

The factors responsible for the lighting scheme for roads are:

i. Luminance Level.
ii. Luminance Uniformity.
iii. Degree of Glare limitation.
iv. Lamp Spectra and
v. Effectiveness of visual guidance.

Luminance Level:

As the Luminance of a road influences contrast sensitivity of drivers' eyes and contrast of obstacles, relative to back ground. Hence affects performance of Road users. Surrounding brightness affects the adaptation of human eye. Bright surroundings lower contrast sensitivity there by requiring higher luminance for the road surface. Darker surroundings make driver adapted to road (assuming road is brighter). Roads with dark surrounds are to be lit by including surroundings. Otherwise drivers cannot perceive objects in the surroundings. CIE 12 recommends that 5m away from the road on either side should be lit by illuminance level at least 50% of that on the road.

Luminance Uniformity:

Adequate uniformity is necessary for visual performance and visual comfort of the user. From visual performance view point, uniformity ratio is defined by U0 = Lmin / Lavg . U0 should not be below 0.4.From visual comfort view point uniformity ratio is defined as U1 = Lmin / Lmax measured along the line passing through the observer positioned in the middle of the traffic facing the traffic flow. Termed longitudinal uniformity ratio.

Glare Limitation:

Physiological or disability glare affect visual performance. Psychological or discomfort glare affect visual comfort. Glare is to be avoided at all costs. Lamp Spectra

Spectral composition determines color appearance of the lamp. The way lamp is going to render color to objects Low pressure sodium vapour lamps give greater visual acuity. Spectrum should be such; there is Great speed of perception, less discomfort glare and shorter recovery time after glare.

Visual Guidance:

Visual guidance guides the road user and hence must for user to get a recognizable picture of the course immediately. This is improved by lamp arrangement that follows the run of the road. More so if turns and intersections are there. Lighting scheme must provide visual guidance. On roads having separate lanes with a separator the lighting columns are located on the separator. As is the custom in large avenues in Metros. On a curve the lighting column is located along the outer column. This gives a clear indication of the run of the road on the curvature. Visual guidance pilots traffic through lights of different colors on different routes.

UNIT-4

INDUSTRIAL HEATING AND WELDING Electric Heating Introduction:

Electric heating is any process in which electrical energy is converted to heat. Common applications include heating of buildings, cooking, and industrial processes. An electric heater is an electrical appliance that converts electrical energy into heat. The heating element inside every electric heater is simply an electrical resistor, and works on the principle of Joule heating: an electric current through a resistor converts electrical energy into heat energy. Alternatively, a heat pump uses an electric motor to drive a refrigeration cycle, drawing heat from a source such as the ground or outside air and directing it into the space to be warmed.

Definition

Dielectric heating (also known as electronic heating, RF heating, high-frequency heating) is the process in which radiowave or microwave electromagnetic radiation heats a dielectric material. This heating is caused by dipole rotation.

Role electric heating for industrial applications:

- When current is passed through a conductor, the conductor becomes hot. When a magnetic material is brought in the vicinity of an alternating magnetic field, heat is produced in the magnetic material.

- Similarly it was found that when an electrically insulating material was subjected to electrical stresses, it too underwent a temperature rise (Dielectric heating).

- There are various method of heating a material but electric heating is considered to be
- far superior for the following reasons:

(i)Cleanliness:

- Due to complete elimination of dust and ash, the charges to maintain cleanliness are minimum and the material to be heated does not get contaminated.

(ii)Ease of control:

- With the help of manual or automatic devices, it is possible to control and regulate the temperature of a furnace with great ease.

(iii)Uniform heating:

- Whereas in other forms of heating a temperature gradient is set up from the outer surface (iv) Low attention and maintenance cost:

- Electric heating equipments normally do not require much attention and maintenance is also negligible.

- Hence labour charges on these items are negligibly small as compared to alternative methods of heating.

Requirement of Heating Material:

i) Low Temperature Coefficients of Resistance

- Resistance of conducting element varies with the temperature; this variation should be small in case of an element.

- Otherwise when switched ON from room temperature to go upto say 1200˚C, the low resistance at initial stage will draw excessively high currents at the same operating voltage.

ii) Resistance coefficient Positive

- If temperature is negative the element will draw more current when hot.

- A higher current means more voltage, a higher temperature or a still lower resistance, which can instability of operation.

iii) High Melting Point

- Its melting point should be sufficiently higher than its operating temperature. Otherwise a small rise in the operating voltage will destroy the element.

iv) High Specific Resistance

- The resistivity of the material used for making element should be high.

- This will require small lengths and shall give convenient size.

v) High Oxidizing Temperature

- Its oxidizing temperature should higher than its operating temperature.
- To have convenient shapes and sizes, the material used should have high ductility and flexibility.

- It should not be brittle and fragile.

vi) Should with stand Vibration

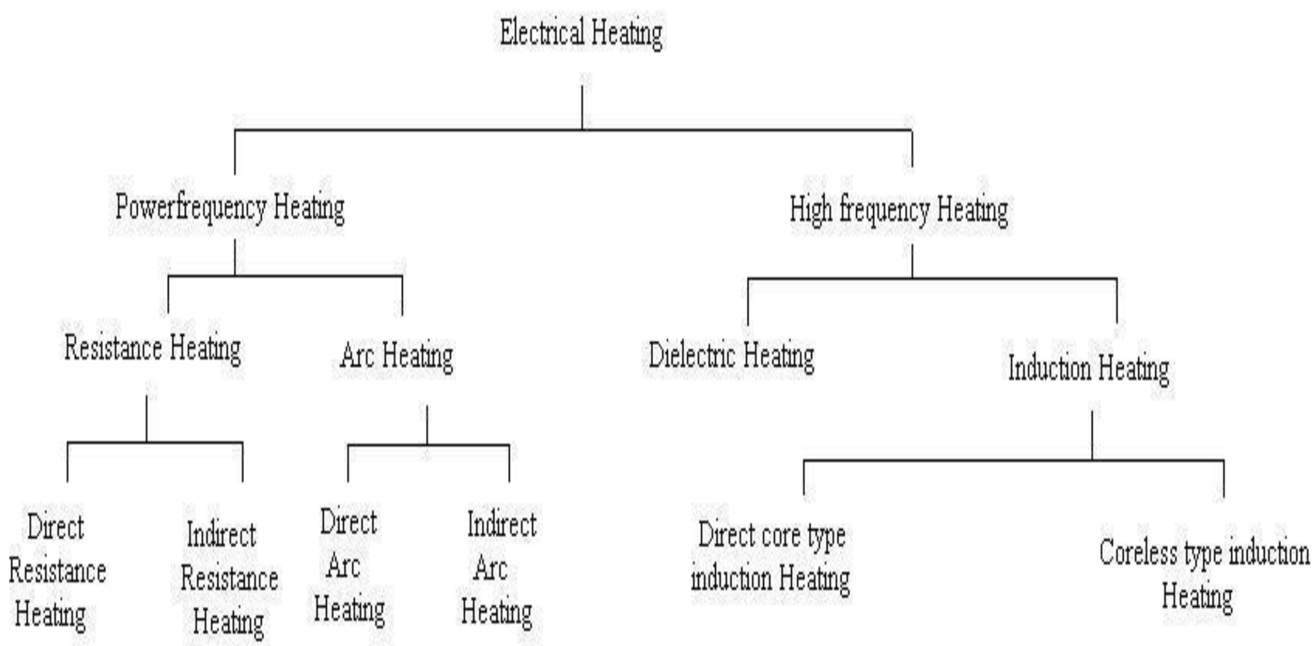
- In most industrial process quite strong vibrations are produced.

- Some furnaces have to open or rock while hot. The element material should withstand the vibrations while hot and should not break open.

vii) Mechanical Strength

- The material used should have sufficient mechanical strength of its own.

CLASSIFICATION OF METHODS OF ELECTRIC HEATING :



i) Power Frequency Method:

- Direct resistance heating, indirect resistance heating, direct arc heating, and indirect arc heating.

ii) High Frequency Heating:

- Induction heating and dielectric heating.

Resistance Heating:

- This method is based upon the I2R loss. Whenever current is passed through a resistive material heat is produced because of I2 R loss.

- There are two methods of resistance heating. They are

a. Direct Resistance Heating

b. Indirect Resistance Heating

Direct Resistance Heating:

- In this method of heating the material or change to be heated is taken as a resistance and current is passed through it.

- The charge may be in the form of powder pieces or liquid. The two electrodes are immersed in the charge and connected to the supply.

- In case of D.C or single phase A.C two electrodes are required but there will be three electrodes in case of three phase supply.

- When metal pieces are to be heated a powder of high resistivity material is sprinkled over the surface of the charge to avoid direct short circuit.
- But it gives uniform heat and high temperature. One of the major applications of the process is salt bath furnaces having an operating temperature between 500˚C to 1400˚C.

- An immersed electrode type medium temperature salt bath furnace is shown in figure

- The bath makes use of supply voltage across two electrodes varying between 5 to 20 volts.

- For this purpose a special double wound transformer is required which makes use of 3Φ primary and single phase secondary. This speaks of an unbalanced load.

- The variation in the secondary voltage is done with the help of an off load tapping switch of the primary side. This is necessary for starting and regulating the bath load.

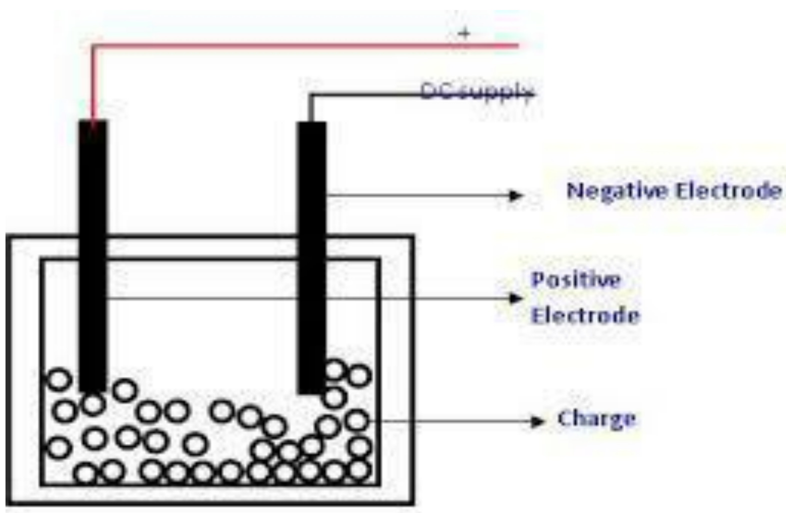
Advantages:

✓ High efficiency.

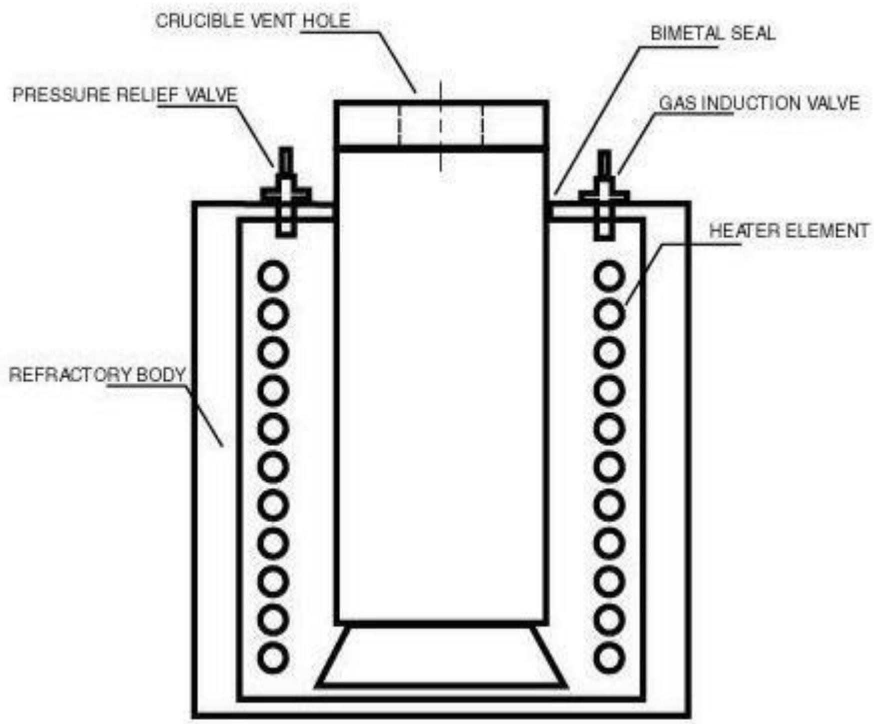
✓ It gives uniform heat and high temperature.

Application:

✓ It is mainly used in salt bath furnace and water heaters.



Indirect Resistance Heating:



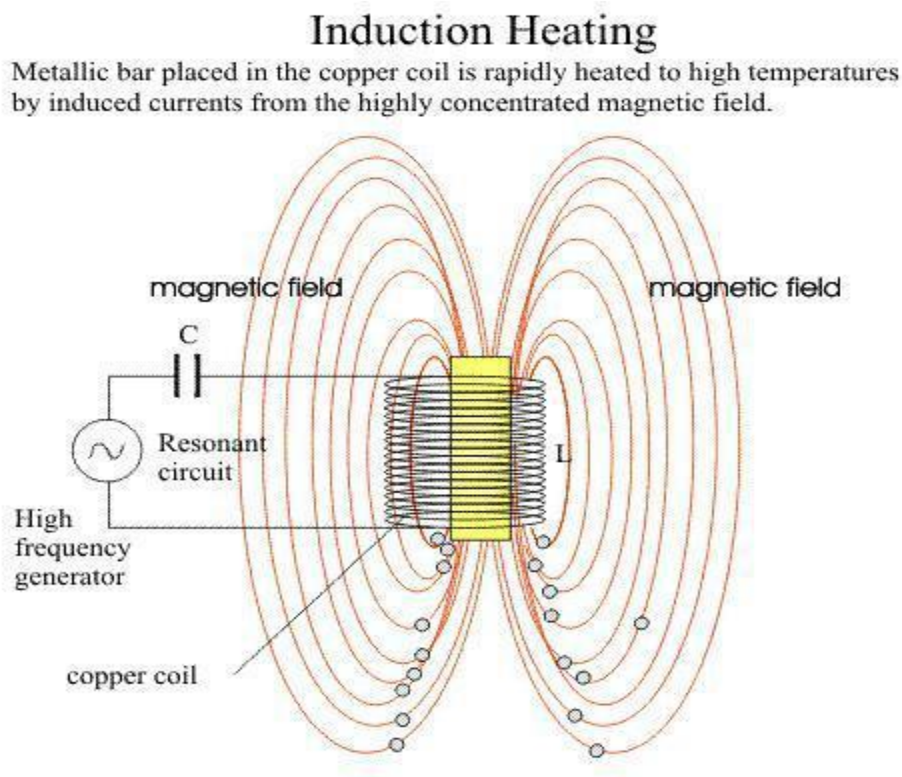
- In this method the current is passed through a highly resistance element which is either placed above or below the over depending upon the nature of the job to be performed.

- The heat proportional to I2R losses produced in heating element delivered to the charge either by radiation or by convection.

- Sometimes in case of industrial heating the resistance is placed in a cylinder which is surrounded by the charge placed in the jackes.The arrangement provides as uniform temperature.

- Automatic temperature control can be provided in this case
- This method is used in room heater, in bimetallic strip used in starters, immersion water heaters and in various types of resistance ovens used in domestic and commercial cooking.

Induction heating:



- Induction heating processes make use of currents induced by electromagnetic action in the material to be heated.

- Induction heating is based on the principle of transformers. There is a primary winding through which an a.c current is passed.

- The coil is magnetically coupled with the metal to be heated which acts as secondary.

- An electric current is induced in this metal when the a.c current is passed through the primary coil.

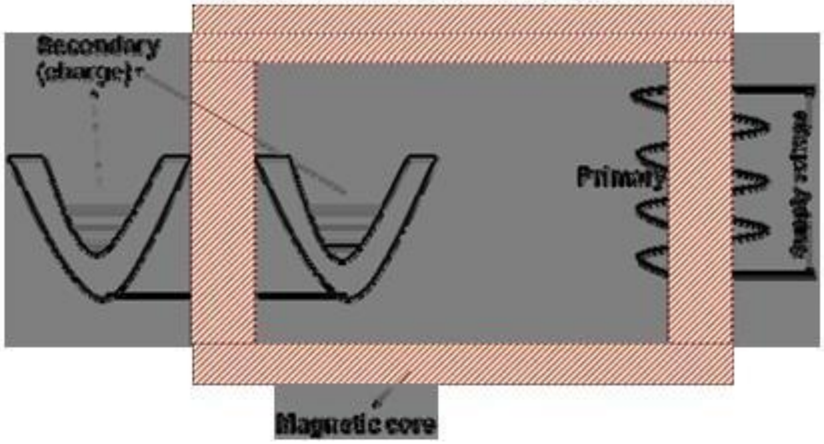
The following are different types of induction furnaces

1. Core type furnaces
a. Direct core type induction furnace
b. Vertical core type induction furnace
c. Indirect core type induction furnace
2. Core less type furnaces

Direct core type:

- The direct core type induction furnace is shown ion fig.

- It consist of an iron core, crucible and primary winding connected to an a.c supply.
- The charge is kept in the cruicible, which forms a single turn short circuited secondary circuit.



- The current in the charge is very high in the order of several thousand amperes. The charge is magnetically coupled to the primary winding.
- The change is melted because of high current induced in it. When there is no molten metal, no current will flow in the secondary.
- To start the furnace molten metal is poured in the oven from the previous charge.

This type of furnace has the following drawbacks:

- The magnetic coupling between the primary and secondary is very weak, therefore the leakage reactance is very high. This causes low power factor.
- Low frequency supply is necessary because normal frequency causes turbulence of the charge.
- If current density exceeds about 5 amps/mm2 the electromagnetic force produced by this current density causes interruption of secondary current.
- Hence the heating of the metal is interrupted. It is called pinch effect.
- The crucible for the charge id of odd shape and inconvenient from the metallurgical point of view.
- The furnace cannot function if the secondary circuit is open.
- It must be closed. For starting the furnace either molten metal is poured into the crucible or sufficient molten metal is allowed to remain in the crucible from the previous operation.
- Such furnace is not suitable for intermittent services.

Indirect core type induction furnace:

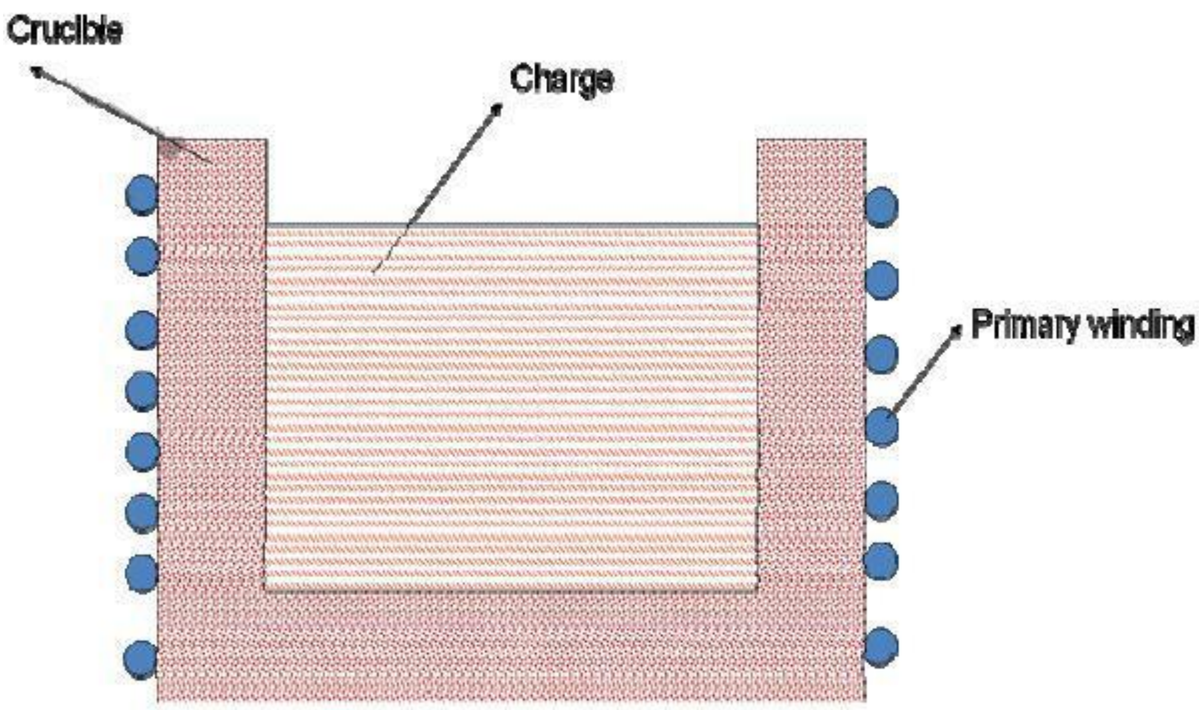
- I n this type of furnace induction principle has been used for heating metals.
- In such furnace an inductively heated element is made to transfer its heat to the change
- When the primary winding is connected to the supply, current is induced in the secondary of the metal container.
- So heat is produced due to induced current. This heat is transmitted to the charge by radiation.
- The portion AB of the magnetic circuit is made up of a special alloy and is kept inside the chamber of the furnace.
- The special alloy will loose its magnetic properties at a particular temperature and the magnetic properties are regained when the alloy will cooled.
- As soon as the furnace attains the critical temperature the reluctance of the magnetic circuit increases many times and the inductive effect correspondingly decreases thereby cutting off the heat supply.

The bar AB is removable type and can be replaced by other, having different critical temperature. Thus the temperature of the furnace can be controlled very effectively.

Coreless induction furnace:

- Coreless induction furnace also operates on the principle of transformer. In this furnace there is no core and thus the flux density will be low.
- Hence for compensating the low flux density, the current supplied to the primary should have sufficiently high frequency.
- The flux set up by the primary winding produces eddy currents in the charge. The heating effect of the eddy currents melts the charge.
- Stirring of the metals takes place by the action of the electromagnetic forces. Coreless furnace may be having conducting or non conducting containers.
- Fig shows a coreless induction furnace in which container is made up of conducting material.
- The container acts as secondary winding and the charge can have either conducting or non conducting properties.
- Thus the container forms a short circuited single turn secondary. Hence heavy current induced in it and produce heat.
- The flux produced by the primary winding produces eddy currents in the charge. The heating effects of the eddy currents melt the charge.

- Stirring action in the metals takes place by the action of the electromagnetic forces.



Advantages:

- ✓ Time taken to reach the melting temperature is less.
- ✓ Accurate power control is possible.
- ✓ Any shape of crucible can be used.
- ✓ The eddy currents in the charge results in automatic stirring.
- ✓ Absence of dirt, smoke, noise, etc.
- ✓ Erection cost is less.

Applications of Induction Heating

- ✓ Induction furnace
- ✓ Induction welding
- ✓ Induction cooking
- ✓ Induction brazing
- ✓ Induction sealing
- ✓ Heating to fit
- ✓ Heat treatment

Advantages of Induction Heating

- ✓ Optimized Consistency

- ✓ Maximized Productivity
- ✓ Improved Product Quality
- ✓ Extended Fixture Life
- ✓ Environmentally Sound
- ✓ Reduced Energy Consumption

Dielectric heating:

- Dielectric heating is also sometimes called as high frequency capacitance heating.

- If non metallic materials ie, insulators such as wood, plastics, china clay, glass, ceramics etc are subjected to high voltage A.C current, their temperature will increase in temperature is due to the conversion of dielectric loss into heat.

- The dielectric loss is dependent upon the frequency and high voltage. Therefore for obtaining high heating effect high voltage at high frequency is usually employed.

- The metal to be heated is placed between two sheet type electrodes which forms a capacitor as shown in fig. The equivalent circuit and vector diagram is also shown in fig.

- When A.C supply is connected across the two electrodes, the current drawn by it is leading the voltage exactly 90˚.

- The angle between voltage and current is slightly less than 90˚

- But at high frequencies, the loss becomes large, which is sufficient to heat the dielectric.

Advantages:

- ✓ Uniform heating is obtained.
- ✓ Running cost is low.
- ✓ Non conducting materials are heated within a short period.
- ✓ Easy heat control.

Applications:

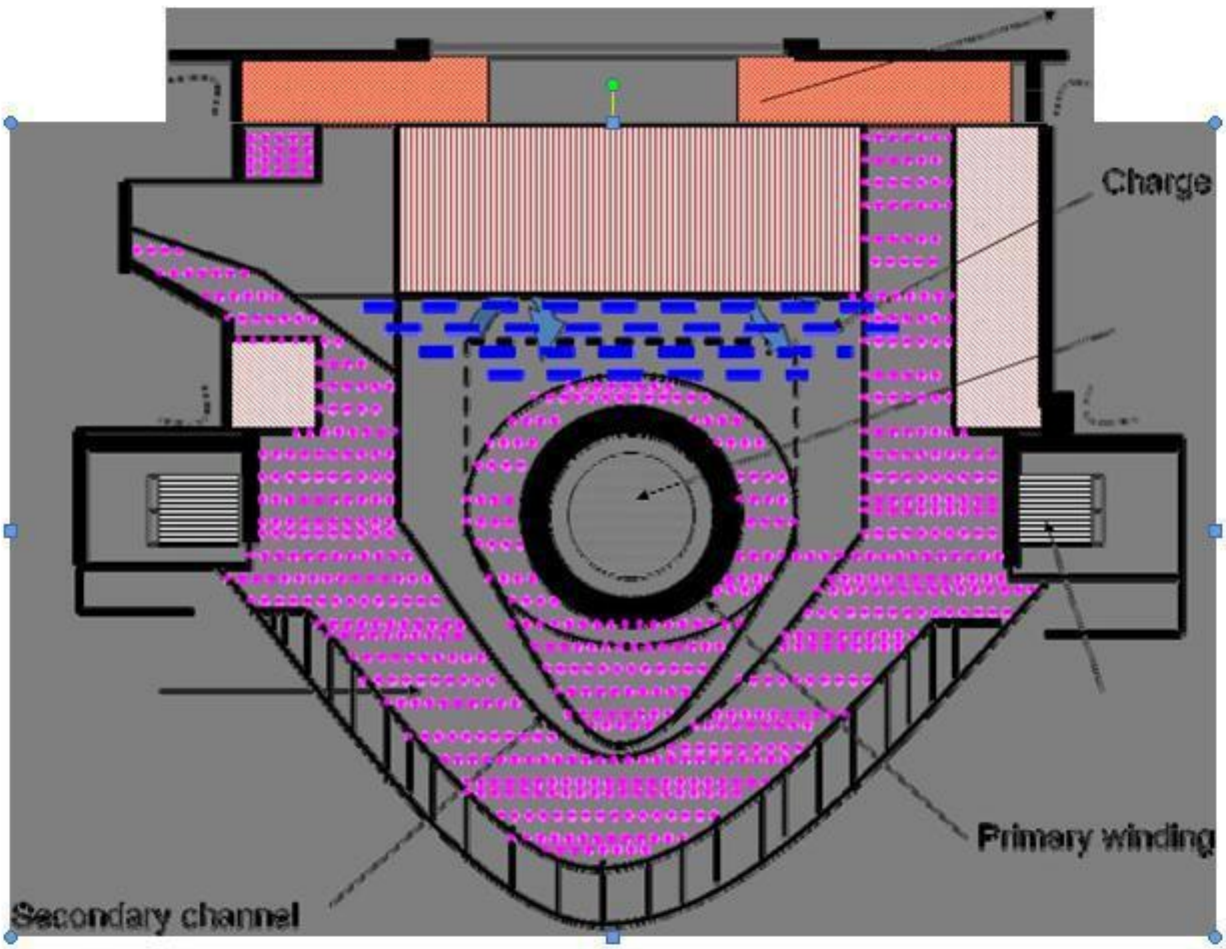
- ✓ For food processing.
- ✓ For wood processing.
- ✓ For drying purpose in textile industry.
- ✓ For electronic sewing.

Electric arc furnaces:

AJAX WYATT Vertical core type furnace:

- The principle of operation is that of a transformer in which the secondary turns are replaced by a closed loop of molten metal. The primary winding is placed on the central limb of the core.

- Hence leakage reactance is comparatively low and power factor is high. Inside of the furnace is lined with refactory depending upon the charge.



The top of the furnace is covered with an insulated cover which can be removed for charging. Necessary arrangements are usually made for titling the furnace to take out the molten metal.

- The molten metal in the 'V' portion acts as a short circuited secondary. When primary is connected to the a.c supply, high current will be accumulated at the bottom and even a small amount of charge will keep the secondary completed.
- Hence a chance of discontinuity of the circuit is less.

Advantages:

✓ High efficiency and low operating cost.

- ✓ Since both primary and secondary are on the same central core, its power factor is better.
- ✓ The furnace is operated from the normal supply frequency.
- ✓ Chances of discontinuity of the secondary circuit is less, hence it is useful for intermittent operations.

Applications:

- ✓ This furnace is used for melting non ferrous metals like brass, zinc, tin, bronze, copper etc.

Introduction to electric welding:

Welding is the process of joining two similar metals by heating. The metal parts are heated to melting point. In some cases the pieces of metal to be joined are heated to plastic stage and are fused together.

The electric welding sets may be either dc or ac type. DC welding sets are of two types namely generator type welding set consisting of a differential compound wound dc generator, giving drooping volt-ampere characteristic, driven by any type of prime-mover (a squirrel cage induction motor or a petrol or diesel engine) and dry type rectifier (selenium rectifier) used in conjunction with a multiphase high leakage transformer. IN generator type welding sets the control may be obtained by tapping the series field or by providing a suitable shunt across the series field winding. In the rectifier type set dc voltage is controlled by regulating the transformer output. If supply from existing dc distribution system is to be used for welding then ballast (resistance) is put in series with the equipment and the control is affected by varying this external series resistance.

In electric welding process, electric current is used to produce large heat, required for joining two metal pieces. There are two methods by which electric welding can be carried out. These are

a) Resistance welding and

b) Arc welding.

Types of electric welding:

1. Resistance welding

a) Seam welding

b) Projection welding

c) Flash welding

2. Arc welding

a) Carbon arc welding

b) Metal arc welding

c) Atomic hydrogen arc welding

d) Inert gas metal arc welding

e) Submerged arc welding.

Resistance welding:

- In resistance welding heavy current is passed through the metal pieces to be welded. Heat will be developed by the resistance of the work piece to the flow of current.

- The heat produced for welding is given by

$H=I^2Rt$

Where,

H= Heat developed at the contact area.

I= Current in amperes.

R= Resistance in ohms.

t= time of flow of current.

Butt welding:

- In this process heat is generated by the contact resistance between two components.

- In this type of welding the metal parts to be joined end to end. Sufficient pressure is applied along the axial direction.

- A heavy current is passed from the welding transformer which creates the necessary heat at the joint due to high resistance of the contact area.
- Due to the pressure applied, the molten metal forced to produce a bulged joint.

- This method is suitable for welding pipes, wires and rods.

ii) Spot welding:

- Spot welding is usually employed for joining or fabricating sheet metal structure. This type of joint only provides mechanical strength and is not air or water tight.

- The plates to be welded are placed overlapping each other between two electrodes, sufficient mechanical pressure is applied through the electrodes.
- The welding current flows through electrodes tips producing a spot weld. The welding current and period of current flow depend on the thickness of the plates.

iii) Arc welding:

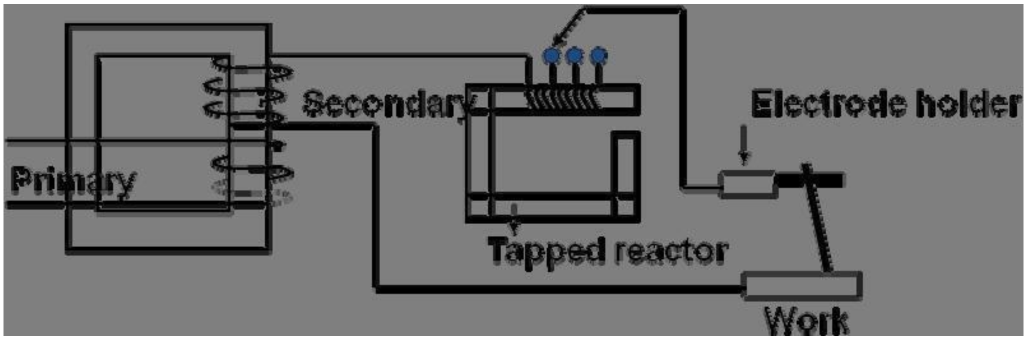
- An electric arc is the flow of electric current through gases.
- An electric arc is struck by short circuiting two electrodes and then with drawing them apart by small distance.
- The current continue to flow across the small gap and give intense heat.
- The heat developed by the arc is also used for cutting of metal.
- The electrode is made of carbon or graphite and is to be kept negative with respect of work.
- The work piece is connected to positive wir. Flux and filler are also used.
- Filler is made up of similar metal as that of metal to be welded.
- If the electrode is made positive then the carbon contents may flow into the weld and cause brittleness.
- The heat from the arc forms a molten pool and the extra metal required to make the weld is supplied by the filler rod.
- This type of welding is used for welding copper and its alloy.

iv) Metal arc welding:

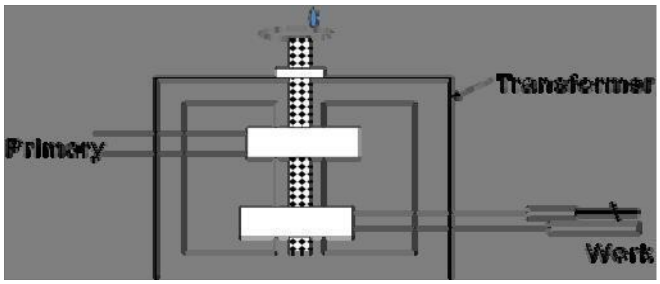
- In metal arc welding a metal rod of same material as being welded is used as an electrode.
- The electrode also serves the purpose of filler. For metal arc welding A.C or D.C can be used.
- Electric supply is connected between electrode and work piece.
- The work piece is then suddenly touched by the electrode and then separated from it a little. This results in an arc between the job and the electrode.
- A little portion of the work and the tip of the electrode melts due to the heat generated by the arc.
- When the electrode is removed the metal cools and solidifies giving a strong welded joint.

WELDING GENERATOR - A.C SUPPLY

In tapped reactor method, output current is regulated by taps on the reactor. This has limited number of current settings.

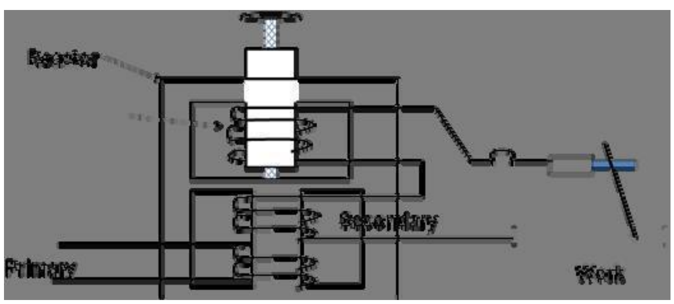


In the moving coil method of current control, relative distance between primary and secondary windings is changed. When coils are more separated out current is less.



In magnetic shunt method, position of central magnetic shunt can be adjusted. This changes the magnitude of shunt flux and therefore, output current. When central core is more inside, load current will be less and vice versa.

In **continuously variable reactor method**, output current is controlled by varying the height of the reactor. Greater the core insertion, greater the reactance and less the output current. Reverse is true for less height of core insertion



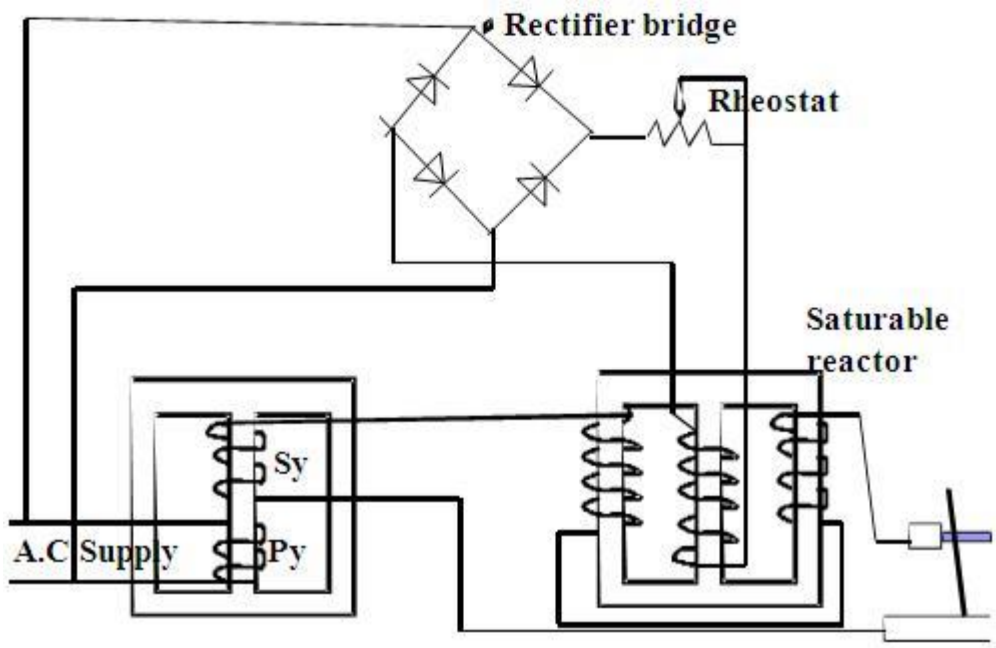
In saturable reactor method, the reactance of the reactor is adjusted by changing the value of d.c excitation obtained from bridge rectifiers by means of rheostat. When d.c current in the central winding of reactor is more, reactor approaches magnetic saturation. This means the reactance of reactor becomes less. Vice versa happens on the

A welding transformer is a step down transformer that reduces the voltage from the source voltage to a lower voltage that is suitable for welding, usually between 15 and 45 volts. The secondary current is quite high. 200 to 600 amps would be typical, but it could be much higher.The secondary may have several taps for adjusting the secondary voltage to control the welding current. The taps are typically connected to a several high-current plug receptacles or to a highcurrent switch. For welding with direct current (DC) a rectifier is connected to the secondary of the transformer.

There may also be a filter choke (inductor) to smooth the DC current. The entire transformer and rectifier assembly may be called a transformer or welder, but "welding power supply" would be more appropriate term.

WELDING TRANSFORMER:

The impedance of a welding transformer may be higher that the impedance of a transformer designed for some other purpose. The transformer impedance may play a role in the process of establishing an arc and controlling the current.



Special Features:

- Stepless current control within single range from front panel
- For its high permitted load, its ideal for fematic welding
- Phase compensation facility optional. It’s a good investment as the primary current and rated output can be reduced, resulting in reduced fuse size and cable diameter
- Provided with wheels and handle for easy mobility
- Sturdy design for all working environments
- Horizontal shunt core travel ensures precise setting after prolonged use
- Class 'H' insulation provides longer coil life
- Multi voltage input supply

UNIT-5
ELECTRIC TRACTION

Merits of electric traction:

- The locomotive in which the driving or tractive force is obtained from electric motors is called Electric traction.

- Electric traction has many advantages as compared to other non-electrical systems of traction including steam traction.

Electric traction is used in:

i) Electric trains

ii) Trolley buses

iii) Tram cars

iv) Diesel-electric vehicles etc.

Traction systems:

All traction systems, broadly speaking, can be classified as follows:

1. Non-electric traction systems:
These systems do not use electrical energy at some stage or the other.

Examples: Steam engine drive used in railways at some stage or the other.
These are further sub divided into the following two groups:

a) Self contained vehicles or locomotives

Examples:
i) Battery-electric drive

ii) Diesel-electric drive

b) Vehicles which receive electric power from a distribution network or suitably placed sub-stations. Examples:
i) Railway electric locomotive fed from overhead A.C supply;

ii) Tramways and trolley buses supplied with D.C.supply.
Here power is applied to the vehicle from an overhead wire suspended above the track.

Electric traction systems may be broadly categorized as those operating on:

1. Alternating current supply

2. Direct current supply.

In general following electric traction systems exist:

a) AC 3 phase 3.7 kV system
b) AC single phase 15/16 kV -161/25 Hz
c) AC single phase 20/25 kV - 50/60 Hz
d) DC 600 V
e) DC 1200 V
f) DC 1.5 kV
g) DC 3 kV.

Advantages:

Electrical transmission, which is usually applied to high power units, has following advantages:

1. It has smooth starting without shocks.
2. Full driving torque is available from standstill.
3. Engine can be run at its most suitable speed range. This given higher efficiency range.
4. Characteristics of traction motor and generator are so chosen that the speed of the traction unit automatically adjusts according to the load and gradient so as to maintain constant output and not to overload the diesel engine.
5. Electrical transmission docs not only work as torque converter but also works as reversion gear.

Requirements of an ideal traction system:

1. High adhesion coefficient, so that high tractive effort at the start is possible to have rapid acceleration.

2. The locomotive or train unit should be self contained so that it can run on any route.

3. Minimum wear on the track.

4. It should be possible to overload the equipment for short periods.

5. The equipment required should be minimum, of high efficiency and low initial and maintenance cost.

6. It should be pollution free.

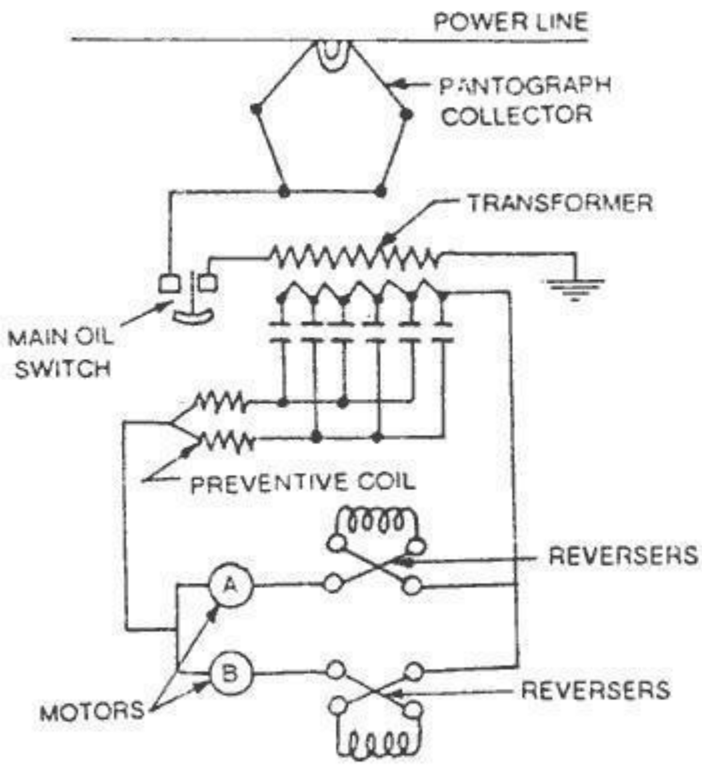
7. Speed control should be easy.

8. Braking should be such that minimum wear is caused on the brake shoes, and if possible the energy should be regenerated and returned to the supply during braking period.

Supply Systems:
Ac single phase system:

In this supply is taken from a single overhead conductor with the running rails. A pantograph collector is used for this purpose. The supply is transferred to primary of the transformer through on oil circuit breaker. The secondary of the transformer is connected to the motor through switchgear connected to suitable tapping on the secondary winding of the transformer.

The switching equipment may be mechanically operated tapping switch or remote controlled contractor of group switches. The switching connections are arranged in two groups usually connected to the ends of a double choke coil which lies between the collections to adjacent tapping points on the transformer. Thus the coil acts as a preventive coil to enable tapping change to be made without short circuiting sections of the transformer winding and without the necessity of opening the main circuit.



Direct current systems:

The transformation and high voltage generation of dc is very inconvenient to the dc supply used is at normally 600 V and this voltage is almost universal for use in urban and suburban railways.
For direct current equipment, the series motor is universally employed as its speed-torque characteristics are best suited to traction requirements. Generally two or more motors are used in single equipment and these are coupled in series or in parallel to give the different runningspeeds required. The motors are initially connected in series with starting rheostats across the contact line and rails, the rheostats are then cut out in steps, keeping roughly constant current until the motors are running in full series. After this the motors are rearranged in parallel, again with rheostats, the rheostats are cut out in

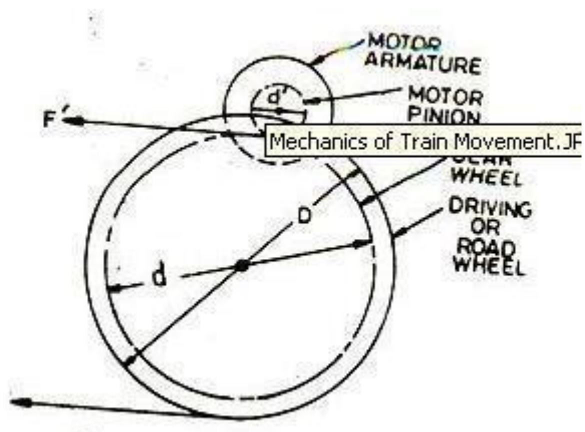
steps, leaving the motors in full parallel. The power input remains approximately constant during the series notching, then jumps to twice this value during the parallel notching. Thus a 4 motor unit will have three economical speeds when the motors are running in series, series - parallel connections. The rheostats are operated electro magnetically or electro-pneumatically.

Mechanics of train movement:

Essential driving mechanism of an electric locomotive is shown in fig. The armature of the driving 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 means of a gear wheel. Tractive effort transferred tot the driving is given by the expression.

$F = = \eta F (d/D0 = \eta 2T/D) = \eta T (2/D) (d/d) = \eta T 2y/D$

Where T is the torque exerted in N-m, by the driving motor, d is the diameter of gear wheel in metres. D is the diameter of driving wheel in metres, η is the transmission efficiency and γ is the gear ratio and is equal to d/d“
For obtaining train motion without slipping tractive effort F should be less than or at the most equal to μW where μ the coefficient of adhesion between the wheel is and the track and W is the weight of the train on the driving axles (called the adhesive weight).



Transmission of Tractive Effort

Traction motors and control:
The control of traction motors for starting and for smooth acceleration is very much essential to avoid damage to the motors. The control equipment is provided for manual and automatic operation. Usually a master controller is used for the purpose.

1) D.C series motor control or plain rheostat control
2) Series –Parallel control

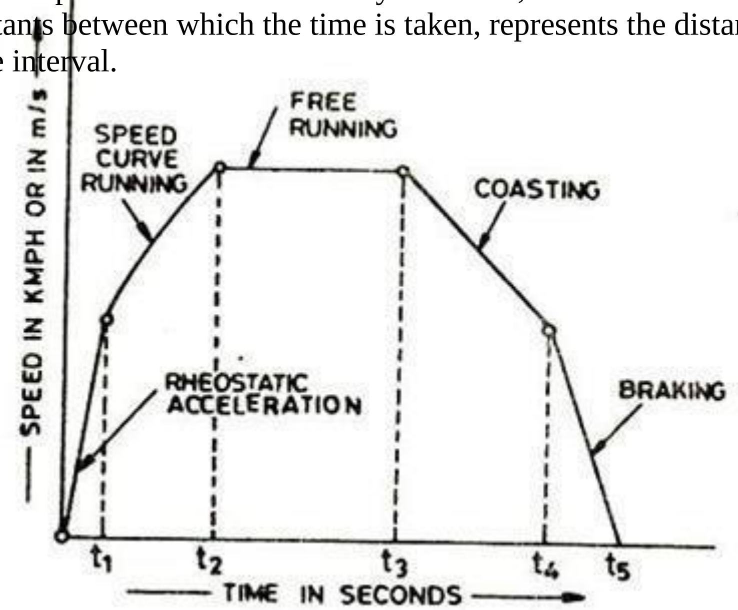
i. Open circuit transition
ii. Shunt transition control

iii. Bridge transition control
3.Metadyne control
4.Multiple unit control

Train Movement and Energy Consumption:

Speed-Time Curves:

The curve drawn between speed and time is called the speed-time-curve. The speed-time curve gives complete information of the motion of the train. The curve gives the speed at various instants after the start of run directly. Slop of the curve at any point gives the acceleration at the corresponding instant or speed. The area covered by the curve, the time axis and the ordinates through the instants between which the time is taken, represents the distance covered in the corresponding time interval.



Speed-time curve mainly consists of

1) Initial acceleration
(a) Constant acceleration or acceleration while notching up
and (b)Speed curve running or acceleration on the speed curve
2) Constant speed run or free run
3) Coasting and
4) Retardation or braking

1. Acceleration period:

From starting to the stage when locomotive attains maximum speed, the period is known as acceleration period, as the vehicle is constantly accelerated. This is represented by OA portion of the curve and time duration is t_1.

2. Free running:

During this period the motor develops enough torque to overcome the friction and wind resistance and hence the locomotive runs at constant speed. This is shown by the portion AB of the curve.

3. Coasting:

When the locomotive is running at certain speed, if the motor is switch off, due to inertia the vehicle will continue to run, of course with little deceleration due to friction and windage.

4. Braking:

The locomotive is retarded to stop it within short distance and at a particular spot. The shape of the curve will change depending upon the distance between consecutive stations .

It is the curve drawn between speed of train in km/hour along y-axis and time in seconds along x-axis.

- The speed time curve gives complete information of the motion of the train.
- This curve gives the speed at various times after the start and run directly.
- The distance travelled by the train during a given interval of time can be obtained by determining the area between the curve and the time axis corresponding to this interval.
- A typical speed time curve for main line service is shown in fig. This curve consists of five sections.

1. Notching up period (0 to t_1)

- During this period of run (0 to t_1), starting resistance is gradually cut so that the motor current is limited to a certain value and the voltage across the motor is gradually increased and the traction motor accelerates from rest.
- To cut the starting resistance, the starter handle has to be moved from one notch to another. Hence this period is called notching up period.
- The acceleration is almost uniform during this period.
- Now the torque decreases and speed increases according to the speed torque characteristics of the motor.
- Now the acceleration gradually decreases with the increase in speed and finally reaches the required torque for the movement of the train (at time t_2).

3. Free running period ($t_2$to t_3).

- During this period i.e. t_2 to t_3 the power supplied to the motor is at full voltage and speed of this period is constant, also during this period

- Power drawn from the supply is constant.

4. Coasting period (t_3 to t_4)

- At the end of free running period supply to the motor is cut off and the train is allowed to run under its own kinetic energy.

- Due to train resistance speed of the train gradually decreases.
- The rate of decreasing of speed during this period is known as “coasting retardation”.

5. Braking or retardation period (t_4 to t_5)

- At the end of coasting period the brakes are applied to bring the train to stop.

- During this period speed decreases rapidly and finally reduces to zero.

Types of services:

- There are three types of electric traction services.

1. Main line service

2. Sub-urban service

3. Urban service

Speed – Time curve for suburban service

- In this type of service the distance between two successive stations is in the range of 1.5 km to 8 km. Fig represents speed-time curve for sub-urban service.

- Acceleration and braking retardation required are high.
- Free running period is not possible and coasting period will be comparatively longer than urban service.

Speed – Time curve for urban or city service

- In city service the distance between the two stations is very short i.e., between 0.75 to 1 km.

- The time required for this run between the adjacent and retardation should be sufficient high.

- Fig shows the speed-time curve for urban or city service. It will be seen that there will be no free running period.

- The coasting period is also small.

Tractive effort:

The effective efforts required to run a train on track are

- Tractive effort needed to provide acceleration (F_a)
- Tractive effort needed to overcome the train resistance (F_r)
- Tractive effort needed to overcome gradients (F_g)

Tractive effort for acceleration (F):

Acceleration = α km/hr/sec

= α x 1000/3600 m/sec2

- When a train is accelerated in a linear direction, its rotating parts like the wheels and armature of motors have to be accelerated in an angular direction.
- Therefore the accelerating mass of the train is greater than the dead mass of the train.
- Generally the effective or accelerating mass is 10% more than the dead mass.

i.e. $M_e = 1.1$ M

- Let the effective mass of train = M_e ton

= 1000 M_e kg.

- Force required for acceleration = Mass **x** acceleration.

i.e., F_a= M_e**x** a

= 1000 M_e**x** α 1000/3600

= 277.8 M_e α Newtons

- Tractive effort to overcome the train resistance (F_r):
- While moving, the train has to overcome the opposing force due to the surface friction and wind resistance.
- The train resistance depends upon various factors such as shape, size, condition of track etc.
- Tractive effort required to overcome the train resistance

F_r = M **x** r Newtons

Where M = Mass of train in tone
Consider that an electric train is moving upwards on a slope

- The dead mass of the train along the slope will tend to bring it downward.
- To overcome this effect of gravity, tractive effort are required in opposite direction.
- Tractive effort to overcome the effect of gravity = F_g

$F_g = M_g \sin\theta$ tone m/sec2

$= 1000\ M_g \sin\theta$ kg m/ sec2

$= 1000\ M_g \sin$ Newton

Where g is the acceleration due to gravity

= 9.81 m/sec2
Θ is the angle of slope.

$F_g = 1000\ M \times 9.81 \sin\theta$ Newton------------- (1)

In railway practice the gradient is expressed in terms of rise or fall in every 100 metres of track and it is denoted by G %

Gradient G = BC /(AC/100)

= (BC/AC) **x** 100
i.e., $G = 100 \sin\theta$

$\sin\theta = G/100$-------------------- **(2)**

Sub the value of sin in eqn (1)

$F_g = 1000\ M \times 9.81 \times G/100$

$F_g = \pm 9.81\ MG$ Newton

Positive sign is to be used for upgradient and negative sign for down gradient.

Braking:

- Braking is very frequent in electric drives to stop a motor in a reasonably short time.
- For example a plannar must quickly be stopped at the end of its stroke and sometimes must quickly be stopped at the end of its stroke and sometimes it is necessary to stop the motor in order to prevent accident
- The essential of a good braking system should be

1) Reliable and quick in its action.

2) The braking force must be capable of being controlled.

3) Adequate means be provided for dissipating the stored energy that is kinetic energy of the rotating parts.

4) In case of a fault in any part of the braking system the whole system must come to instantaneous rest or result in the application of the brakes.

- There are two types of braking:

1) Mechanical braking:

The motor in this case is stopped due to friction between the moving part of the motor and the brake shoe that is stored energy is dissipated as heat by a brake shoe or brake lining which rubs against a brake shoe or brake lining which rubs against a brake drum.

2) Electric braking:

In this method of braking, the kinetic energy of the moving parts that is motor is converted into electrical energy which is consumed in a resistance as heat or alternatively it is returned to the supply source.

- During braking operation a motor has to function as a generator.
- The motor can be held at stand still. In other words the electric braking cannot hold the motor at rest.

- Thus it becomes essential to provide mechanical brakes in addition to electric braking.

- Various types of electrical braking are:

a) Plugging
b) Rheostatic braking

c) Regenerative braking

Plugging :

- This is a simple method of electric braking and consists in reversing the connections of the armature of the motor so as to reverse its direction of rotation which will oppose the original direction of rotation of the motor and will bring it to zero speed when mechanical brakes can be applied.

- At the end of the braking period the supply to the motor is automatically cut off.
- This method of braking can be applied to the following motors.

1) DC motors

2) Induction motors

3) Synchronous motors

Plugging applied to DC motors:

To reverse a DC motors, it is necessary to reverse the connections of the armature while the connections of the field are kept the same.

The direction of m.m.f remains the same even during braking periods.

Series motors:

- Total voltage of $V + E_b$ is available across the armature terminals which causes a current I to flow around the circuit.

- When $E_b = V$ then the voltage across the armature is 2V and at the time of braking twice the normal voltage is applied to the resistance in series with the armature at this time in order to limit the current.

- While the motor is being braked, the current is still being drawn from the supply.
- This method requires energy from the supply for its action and not only the kinetic the energy of motor is being wasted, but this energy is also being dissipated.

Speed and braking torque

Electric braking to torque

$T_B \alpha \Phi I$ ---------------------------- (1)

$T_B = K \Phi I$ ---------------------------- (2)

Where K is a constant
Current = $V + E_b / R$ -------------------- (3)

$E_b = K_1 N \Phi N$ --------------------- (4)
is the speed

K_1 is a constant

Substitute the value of E_b from equation (4) in (3)

Current $I = (V + K_1 N \Phi)/ R$ -------------------- (5)

In view of equations (2) and (5)

$T_B = K \Phi[(V + K_1 N \Phi)/ R]$

$= K\Phi V/R + KK_1 N\Phi 2/R$

$= K_2\Phi + K_3\Phi 2N$ --------------------- (6)

Where $K_2 = KV/R$ --------------------- (7)

And $K_3 = KK_1/R$ (8)

Apply the results obtained to the series motor, where

Φ α armature current (I_a)------------------ (9)

Then Electric braking in series motor,

$= K_4 I_a + K_5 I_a 2$-------------------- (10)

In the case of shunt motor since flux is constant

Electric braking torque:

Wherever there is a load on the machine the load will also exert braking torque due to it and then the total braking torque (T)

T = Electric braking torque + Load torque ---------------- (12)

Plugging applied to induction motors:

- In the case of induction motor its speed can be reversed by inter changing any of the two stator phases which reverses the direction of rotation of motor field.
- Actually at the time of braking when the induction motor is running at near synchronous speed.
- The point Q represents the torque at the instant of plugging one can notice that the torque increases gradually as one approaches the stand still speed.
- Different values of rotor resistance give rise to different shapes of speed torque curve in order to

give any desired braking effect.

- The rotor current I_2 can be calculated during the braking period from the following relation and is plotted as shown.

$I_2 = SE_2/ \sqrt{[R_e2 + (SX_2)2]}$ ------------------- (13)

Where E2 is the e.m.f. induced in rotor at standstill

R_2 is the rotor resistance

X_2 is the standstill reactance of the rotor and

S_2 is the percentage slip

Plugging applied to synchronous motors

- Plugging can be applied to the synchronous motors, with the only difference that the field on the rotor will be rotating in opposite direction to that of the rotating field on the stator with the synchronous speed and the relative velocity between the two will be twice the synchronous speed.Rheostatic braking

- In this method of braking, the motor is disconnected from the supply and run as generator driven by the remaining kinetic energy of the equipment that is the energy stored in motor and load which are to be braked.

The following drives can be braked by the rheostatic method:

1) DC motor

2) Induction motor

3) Synchronous motor

Dc motors

Shunt motor:

- In this type of motor, the armature is simply disconnected from the supply and is connected to as resistance in series with it, the field; winding remains connect to the supply.

- The braking can be adjusted suitably by varying the resistance in the armature circuit.

- In the case of failure of the supply, there is no braking torque because of absence of the field.

Series motor:

- In this case of the connections are made as shown is fig during braking operation.

- The motor after disconnection from the supply in made to run as a DC series generator.

- Braking torque and speed

Electric braking torque is given by equation (3)

Braking current = E_b/ R---------------------------------- (14)

Hence braking current of equation (14) and (4)

= $K_1\Phi N/R$ ---------------------------------- (15)

Substitute the value of braking current is equation (1)

Electric braking torque = $KK_1\Phi 2N/R$

= K_2 $\Phi 2N$ ---------------------------------- (16)

Where $K_2 = KK_1/R$ (17)

In the case of a series motor the flux dependent upon the armature current

Electric braking torque for series motor

= K_3I_a2N-------------------------------- (18)

While in the case of shunt motor since flux is constant

Electric braking torque = K_4N (19)

Rheostatic braking is applied to induction motor:

- In this case the stator is disconnected from the supply and is connected to DC supply which excites the windings thereby producing a DC field.

- The rotor is short-circuited across through resistance in each phase.

- When the short circuited rotor moves it outs the steady flux produced in the air gap due to DC current flowing in the stator produced in the air gap due to DC current flowing in the stator and an e.m.f is induced in the rotor conductors Rheostatic braking in the synchronous motors is similar to the rheostatic braking in induction motors.

- In this case the stator is shorted across resistance in star or delta and the machine works like an alternator supplying the current to the resistance, there by dissipating in kinetic energy in the form of losses in the resistances.

Regenerative braking:

- In this type of braking the motor is not disconnected from the supply but remains connected to it and its feeds back the braking energy or its kinetic energy to the supply system.

- This method is better than the first and second methods of braking since no energy is wasted and rather it is supplied back to the system.
- This method is applicable to following motors:

1) D.C motors
2) Induction motors

D.C motors:

Shunt motor:

- In a DC machine where energy will be taken from the supply or delivered to it depends upon the induced emf, if it in less than the line voltage the machine will operate as motor and if it is more than the line voltage, the machine will operate as generator.

The e.m.f induced in turn depends upon the speed and excitation that is when the field current or the speed is increased the induced e.m.f exceeds the line voltage and the energy will be field into the system.
This will quickly decrease the speed of the motor and will bring it to rest.

Series motor:

- In this case, complications arise due to fact that the reversal of the current in the armature would cause a reversal of polarity of the series field.
- In the case of induction motors, the regenerative braking is inherent, since an induction motor act as a generator when running at speeds above synchronous speeds and it feeds power back to the supply system.
- No extra auxiliaries are needed for this purpose.
- This method is however very seldom used for braking but its application is very useful to lifts and hoists for holding a dending load at a speed only slightly above the synchronous speed.

Tramways:

- The tramway is perhaps the cheapest type of transport available in very dense traffic.
- It receives power through a bow collector or a grooved wheel from an overhead conductor at about 600 V D.C., the running rail forming the return conductor.
- It is provided with atleast two driving axles in order to secure necessary adhesion, start it from either end and use two motors with series- parallel control.
- Two drum-type controllers, one at each end used for controlling the tramcar.
- Though these controllers are connected in parallel, they have suitable interlocking arrangement to prevent their being used simultaneously.
- The main frame of the car body is made from high tensile steel. Aluminium is extensively used for bodywork.
- The under frame is of rolled steel sections. Seats are either in transverse direction or a combination of transverse and longitudinal arrangement is used.
- The equipment is similar to that used in railways but the output is considerably smaller and does not exceed 60 to 75 H.P.

- For normal service rheostatic and mechanical braking are employed.

- For mechanical braking, electro-mechanical drum brakes are used. Also magnetic tracks brakes are used for giving better retardation.

Trolley-Bus:

- Serious drawback of tramway is the lack of manoeuvrability in congested areas and noise; this is overcome by the trolley-bus drive.

- It is an electrically- operated pneumatic-tyred vehicle which needs no track in the roadway. It receives its power at 600 V D.C. from two overhead contact wires.
- A D.C compound motor of output of 50 to 100 kW is normally used.

- Speed control is obtained by field weakening method. Foot operated master controllers are used so that drive may have his hands free to steer the vehicle and apply hand brake. One pedal controls the starting, speed control and regenerative braking, if any and second pedal control rheostatic and compressed air brakes. Regenerative braking is usually not employed in trolley-bus drive because of difficulty of ensuring that supply system is always in a position to absorb the energy regenerated.

- The lighting system in the car is low-voltage D.C supplied from a motor- generator set connected in parallel with a battery. The vehicles are usually provided with secondary batteries so that the vehicles can be manoeuvred in case of emergency.

- Since the body of the car is insulated from earth on account of the rubber-tyred wheels, it must be properly checked for adequate insulation resistance lest it leaks and causes electric shocks to the passengers while boarding and alighting from the bus. The insulation resistance is checked at the end of the day.

- Trolley – buses have more passenger carrying capacity, higher acceleration and braking retardation than oil-engined buses. These are, therefore, used for medium traffic density as obtained in inner suburbs. Oil engine buses, on the other hand, are used for outer suburbs and country side where there is low traffic density.

Recent trends in electric traction:

- **Magnetic levitation**, **maglev**, or **magnetic suspension** is a method by which an object is suspended with no support other than magnetic fields. Magnetic pressure is used to counteract the effects of the gravitational and any other accelerations.

- Earnshaw's theorem proves that using only static ferromagnetism it is impossible to stably levitate against gravity, but servomechanisms, the use of diamagnetic materials,superconduction, or systems involving eddy currents permit this to occur.

- In some cases the lifting force is provided by magnetic levitation, but there is a mechanical support bearing little load that provides stability. This is termed **pseudo-levitation**.

- Magnetic levitation is used for maglev trains, magnetic bearings and for product display purposes.

Mechanical constraint (pseudo-levitation):

- With a small amount of mechanical constraint for stability, pseudo-levitation is relatively straightforwardly achieved.

- If two magnets are mechanically constrained along a single vertical axis, for example, and arranged to repel each other strongly, this will act to levitate one of the magnets above the other.

- Another geometry is where the magnets are attracted, but constrained from touching by a tensile member, such as a string or cable.

- Another example is the Zippe-type centrifuge where a cylinder is suspended under an attractive magnet, and stabilized by a needle bearing from below.

Diamagnetism:

Diamagnetism is the property of an object which causes it to create a magnetic field in opposition to an externally applied magnetic field, thus causing a repulsive effect. Specifically, an external magnetic field alters the orbital velocity of electrons around their nuclei, thus changing the magnetic dipole moment. According to Lenz's law, this opposes the external field.Diamagnets are materials with a magnetic permeability less than $\mu 0$ (a relative permeability less than 1). Consequently, diamagnetism is a form of magnetism that is only exhibited by a substance in the presence of an externally applied magnetic field. It is generally quite a weak effect in most materials, although superconductors exhibit a strong effect. Diamagnetic materials cause lines of magnetic flux to curve away from the material, and superconductors can exclude them completely (except for a very thin layer at the surface).

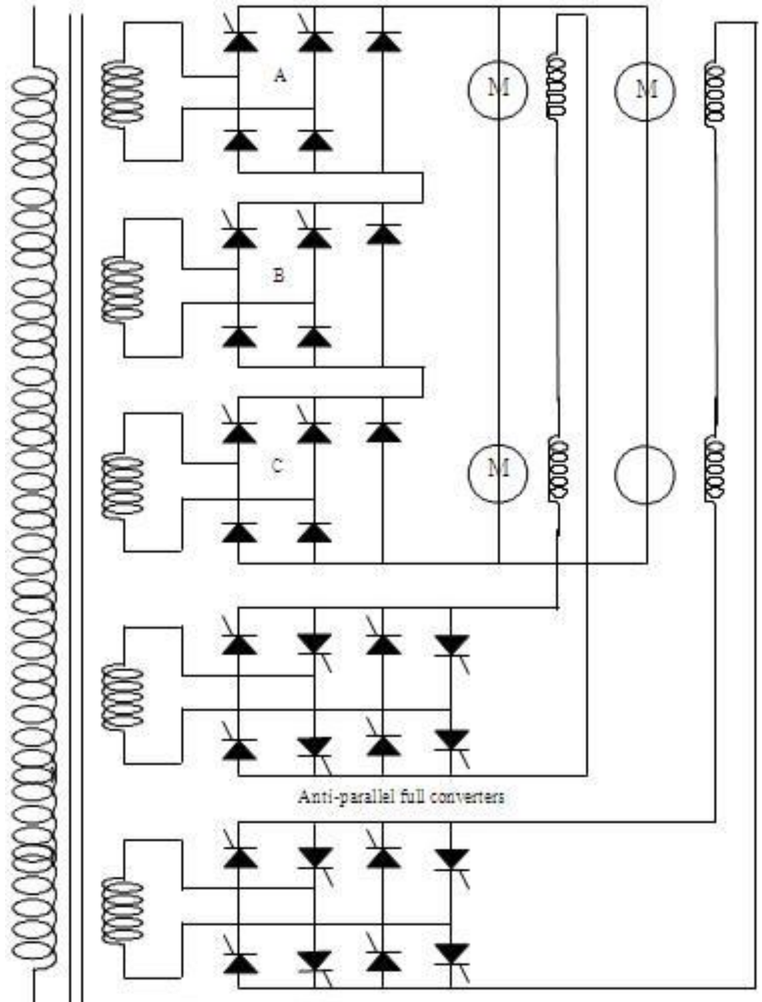
Direct diamagnetic levitation:

- A substance that is diamagnetic repels a magnetic field. All materials have diamagnetic properties, but the effect is very weak, and is usually overcome by the object's paramagnetic or ferromagnetic properties, which act in the opposite manner. Any material in which the diamagnetic component is strongest will be repelled by a magnet.

- Earnshaw’s theorem does not apply to diamagnets. These behave in the opposite manner to normal magnets owing to their relative permeability of $\mu_r < 1$ (i.e. negative magnetic suptibility).

- Diamagnetic levitation can be used to levitate very light pieces of pyrolytic graphite or bismuth above a moderately strong permanent magnet. As water is predominantly diamagnetic, this technique has been used to levitate water droplets and even live animals, such as a grasshopper, frog and a mouse. However, the magnetic fields required for this are very high, typically in the range of 16 teslas, and therefore create significant problems if ferromagnetic materials are nearby.

The modern trend is towards the use of d.c motors (both separately excited and d.c series motors) equipped with thyristor control. The operating voltages are 600V or 1,000V. Braking employed are mechanical, rheostatic and regenerative, Thyristorised converters provide accurate control and fast response. Main advantages of thyristor control are the absence of bulky on load tap changer and electromagnetic devices, saving of energy, notch less control, increase in pulling ability of the motive power, and minimum wear and tear because of absence of conventional moving parts in the motor control circuits.



Thyristorised DC Electric traction system

In electric traction, it is desirable that the train accelerates and decelerates at a constant rate for the comfort of the passengers. Using thyristors, this objective can be met in the following way:
When the speed goes down during breaking the generator voltage decreases. For a particular braking torque a particular armature current is required. This is achieved by increasing the field excitation to a relatively high value. If, however, the generator voltage exceeds the supply voltage, in dynamic braking, this increase is permissible as the armature is not connected to the supply and the energy of the generator can be dissipated in the braking resistors, external resistances in series with the armature are connected in case of regenerative braking to absorb the voltage difference between the armature voltage and supply voltage. With this, of course, part of the generated power is wasted in the external resistors and the efficiency of the overall system is decreased.
Various methods of speed control and electric braking employing thyristors have already been studied in power electronic subjects. In addition to ordinary phase control methods, **cycle selection methods** of control of SCR for varying the voltage applied to the traction motors are also employed. In this method the required average voltage is obtained by accepting or rejecting a certain numbers of complete half cycles. In practice, at the start only one half out of eight is accepted and as the speed

builds up, it is gradually raised to 2/8, 3/8 and finally 8/18 for full power operation. This method is advantageous due to low frequency harmonics, low rate of rise of current, better power factor etc.

In **chopper control** of traction motors, at start, the *'on'* period of pulse is kept very short which lengthens during the period of controlled acceleration. Thus the average voltage applied across the traction motors is gradually increased keeping the mean value of the input current close to the desired value.Fig. shows a typical thyritorised dc traction system supplying a group of four separately excited motors. The armatures are supplied from half controlled bridge converters. However, it is desirable to feed the field windings through fully controlled bridge converters so as to reduce the ripple in the field current. Low ripple in the field current ensures low iron losses in the machines. However, if regenerative braking is required then the armature should be supplied from fully controlled bridges. Freewheeling diodes are connected as illustrated to ensure good waveform of armature current. The armatures are connected in series – parallel arrangement to ensure good

starting and running characteristics. It is seen that armatures are supplied by three bridges connected in series. For starting first only bridge A is triggered and firing angle is advanced as speed builds up. When bridge A is fully conducting (i.e. when α=0), bridge B is triggered and then bridge C is triggered. During starting field currents are set to maximum to provide high starting torque. The use of three bridges ensures better power factor than would be possible with a single bridge.

QUESTION BANK
UNIT 1
GENERATION

1) What are the sources of energy?
Electrical energy is produced from energy available in various forms in nature. The sources of energy are

- The Sun
- The wind
- Water
- Fuels
- Nuclear energy

2) Name the different types of power generation.
Conventional methods (With prime movers)
a) Hydro power generation
b) Thermal power generation
c) Nuclear power generation

d) MHD (magneto hydro dynamic) power generation
e) Solar power generation
f) Fuel cells generation
g) Thermo electric generation
h) Thermionic converters
i) Solar cells
j) Wind power generation
k) Geo-thermal energy generation
L) Tidal power generation

3) What are the limitations of conventional energy
sources? 1. Resources are limited some are seasonal
2. Most of them emit harmful gases contributing to global warming
3. Situated in remote areas and higher T and D losses
4. Requires large areas

4) How will you classify hydro-electric plants according to nature of
load? Classification according to nature of load

- Base load plants
- Pear load plants
- Pumped storage plants for peak load.

5) What is the principle of Hydel power generation?

6) What are the types of hydel power generation?

- System based on falling water
- System based on natural flow of river
- current Pumped storage system

7) How are hydel stations classified according to the head?

- Low head less than 30 meters Francis turbines
- Medium head 30 to 100 meters Francis and Kaplan turbines
- High head 100 meters and above Kaplan turbines

8) What is penstock?

From the reservoir the water is carried to valve house through pressure tunnel and from valve house to the water turbine through pipes of large diameter made of steel or reinforced concrete, called the penstock.

9) What is the principle of pumped storage scheme?

The basic principle of pumped storage scheme is to convert the surplus electrical energy generated by a power plant or available in a system in off-peak periods, to hydraulic potential energy, in order to generate power in periods where the peak demand on the system exceeds the total available capacity of the generating stations.

10) What are the factors to be considered while selecting a site for steam power plants?

The factors to be considered for selecting the steam power plant are as follows:

- Nearness to the load centre
- Availability and supply of cooling
- water Availability of coal
- Land requirement
- Transport facilities and Ash disposal facilities.

11) What is the function of deaerator in steam power plant?

The function of deaerator is to reduce dissolved oxygen content in the condensate i.e. in the feed water. The feed water is then pumped into boiler through economizer in which it is further heated by the heat of the flue gas passing through it on the way to chimney.

12) What are the disadvantages of steam power
plants? The disadvantages are

- High maintenance and operating cost.
- Pollution of atmosphere due to fumes and residues from pulverized
- fuels. Requirement of water in huge quantity.
- Handling of coal and disposal of ash is quite difficult.
- Troubles from smoke and heat from the plant. Requires
- long time for erection and put into action.

13) What is nuclear fission?

In nuclear station, heavy elements such as Uranium (U235) or Thorium (Th232) are subjected to nuclear fission in a special apparatus known as reactor. Fission:

The breaking up of nuclei of heavy atoms into two nearly equal parts with release of huge amount of energy is known as nuclear fission.

14) What are the components of nuclear reactor?

The nuclear reactor consists of the following basic

- components Reactor core
- Moderator
- Control rods
- Coolant
- Reflector
- Thermal shielding
- Reactor vessel
- Biological shield.

15) What are the merits of nuclear power plants? The advantages are

- The amount of fuel required is small; therefore, there is no problem of transportation, storage etc.
- The demand for coal, oil and gas is reduced which are tending to rise in cost as the stocks are becoming depleted.
- These plants need less area as compared to any other plant. A 2000MW nuclear plant needs 80 acres whereas thermal stations need about 250 acres of land.
- Most economical in large capacity.The operating cost is quite low and once the installation is completed, the loading of the plant is always operated as a base load plant.

16) What is the principle of wind power generation?

Converts kinetic energy in moving air (wind) into electrical energy. If mechanical energy is directly used it is called a wind mil.e.g.Pump. If mechanical energy is used to generate electrical energy and then used it is a wind energy converter. Clusters of wind mills is called a wind form.Winds are essentially caused by the solar heating of the atmosphere. They carry enormous quantity of energy. Wind as a source of power is very attractive because it is plentiful, inexhaustible, renewable and non-polluting. There is no depletion of scarce resources. In large portion of the world, wind blows for 320 days in a year and this gives them an advantage over sunlight in direct conversion programmes, operating cost of a wind mill is negligible. Further, it does not impose extra burden on the environment.

The ideal maximum efficiency using Froud momentum theory is equal to 59% but an overall efficiency of 30% could be had due to aerodynamic and other mechanical losses. This gives a power of about 0.3KW/sq.m for a wind velocity of 10m/s.

17) What is the principle of MHD power generation?

Direct conversion of kinetic energy of a flowing liquid in to electricity Faradays law of electro magnetic induction .By forcing a high pressure high temperature combustion gas through a strong magnetic field

18) What is the principle of GEO THERMAL power generation?

Residual thermal energy is left over in fluids in deep reservoirs within the earth’s crest left over by planets origin. Hot natural supply of water which can produce steam by the hot under ground magma is exhausted and processed.

19) What is the principle of solar generation?

Solar energy the energy produced in the sun and collected on the earth. Energy from sun in the form of heat and light is harnessed. Solar heating system uses the heat energy and solar electric system uses light energy (photo voltic cell) to generate electrical energy.

20) What is the principle of tidal power generation?

Tidal movements of tides in seas are due to difference in water levels caused by

(1) Gravitational forces between the Sun, moon and the earth and

(2) Rotation of the moon and earth.

The kinetic energy of moving tides and the potential energy difference between the high tides and the low tides can be converted into electrical energy.

21) What are the advantages of MHD generation? The advantages are

- The conversion efficiency is around 50% to 60%.
- No moving part, so more reliable.
- Capital cost is less compared with conventional steam
- plants. Overall generation cost is less.
- Economic and reduced fuel consumption.

- The closed cycle system produces power free of pollution.
  Elimination of energy losses.

22) What is solar cell?

The solar cells operate on the principle of photo voltaic effect, which is a process of generating an emf as a result of the absorption of ionizing radiation.It is possible to convert solar energy directly into electrical energy by means of silicon wafer photo-voltaic cells, also called the solar cells, without any intermediate thermodynamic cycle.Thus a solar cell is a transducer, which converts the sun's radiant energy directly into electrical energy and is basically a semi-conductor diode capable of developing a voltage of 0.5-1volts and a current density of 20-40 mA/sq.cm depending on the materials used and the conditions of sunlight.

23) What are the types of collectors used in solar power generation?

Types of collectors

- Flat plate collectors(60°C) Focusing or
- concentrating collectors Cylindrical parabolic
- concentrator (100-200°C) Paraboloids, Mirror
- Arrays(<200°C)

24) What is tide?

TIDE is a periodical rise and fall of the water level of sea which are carried by the action of the sun and moon on thewater of the earth.

The main feature of the tidal cycle is the difference in water surface elevations at the high tide end, the tidal energy can be converted into electrical energy by means of a generator.

25) What is the function of moderator in nuclear power plant?

- A nuclear reactor is a cylindrical stout pressure vessel and houses fuel rods of Uranium, moderator and control rods. The fuel rods constitute the fission material and release huge amount of energy when bombarded with slow moving neutrons.
- The moderator consists of graphite rods which enclose the fuel rods. The moderator slows down the neutrons before they bombard the fuel rods.

26) What are the merits and demerits of tidal power generation?

The advantages of tidal power are

- It is free from the problems of uprooting the people and disturbing the ecology balance.
- It is everlasting and is not influenced by the charging mood of the nature such as failure of the monsoon.
- No extra submerging of land is involved.
- The major drawback of tidal power plants is their uneven operation. Variations in the tidal energy available through the lunar day and lunar month different from their solar counterparts prevent the tidal power from being regularly used in power systems during the periods of peak demand.

27) What is thermal efficiency?

The ratio of heat equivalent of mechanical energy transmitted to the turbine shaft to the heat of combustion of coal is known as Thermal efficiency of Steam power station.

28) What are the types of wind mills?

Wind energy conversion system are classified into two types,

i) Horizontal axis wind mills

The axis of rotation is horizontal and in the aero turbine, plane is vertical facing the wind.

ii) Vertical axis wind mills

The axis of rotation is vertical, the blades also be vertical.

29) Define a distributed generation system?

It is a system of modular power generators at are near the customers sites and loads It potentially provide an economic value to the consumers as well as the power grid.

30) What is meant by islanding w.r.to interconnection of distributed generation system connected to the grid?

When a distributed generation system gets disconnected from the grid and when it continues to feed the local loads the situation is called islanding.

31) How does islanding of a distributed generation system connected to the grid affect the power system?

1. over and under voltage
2. over and under frequency
3. Phase jump
4. Voltage harmonics

32) What are the effects of a distributed generation system on a power system?

1. Affects over current protection setting
2. Affects auto reclosing
3. Creates Ferro resonance
4. Causes insulation failure
5. Islanding creates power quality problems

33) What are the functions of power electronic interface in a distributed generation system connected to the grid?

1. dc to ac conversion
2. to improve power quality

UNIT-II
ECONOMIC ASPECTS OF GENERATION

1) What do you mean by Economics of power generation?

The art of determining the per unit i.e. one KWh cost of production of electrical energy is known as Economics of power generation.

2) Explain the term depreciation.

The decrease in the value of the power plant equipment and building due to constant use is known as depreciation.In practice, every power station has a useful life ranging from fifteen to thirty years. From the time the power station is installed, its equipment steadily deteriorates due to wear and tear so that there is a gradual reduction in the value of the plant. This reduction in the value of plant every year is known as annual depreciation.

3) Define load factor.

Load factor is the ratio of average demand to the maximum demand during a certain period of time and is applicable to both generating equipment and receiving equipment. Load factor = Average demand/Maximum demand

4) What is load curve?

The curve showing the variation of load on the power station with reference to time is known as a load curve.

The load curves supply the following information

- The variation of the load during different hours of the day.
- The area under the curve represents the total number of units generated in a day.
- The peak of the curve represents the maximum demand on the station on the particular day.
- The area under the load curve divided by the number of hours represents the average load on the power station.

- The ratio of the area under the load curve to the total area of the rectangle in which it is contained gives the load factor.

5) Define diversity factor.

Diversity factor is defined as the state of being dissimilar to one another. It is defined as the ratio of sum of the maximum demands of individual consuming units in a group during a specified period to the maximum demand of the whole group during the same period.

Diversity factor = Sum of individual demands of different units in a group/Maximum demand of the entire group

The value of diversity factor is always greater than one. If thediversity factor is higher, the cost per unit of generation will be lesser.

6) What do you mean by utilisation factor?

It is a measure of the utility of the power plant capacity and is the ratio of maximum demand to the rated capacity of the power plant. It is always less than unity.

Utilization factor = Maximum Demand on the power station/Rated capacity of the power station

A low value of utilization factor indicates that the plant has been installed much in advance of need. A high value indicates that the plant is probably most efficient in the system. If its value exceeds unity, it means that the load has been carried in excess of rated capacity of the plant.

7) Write short note on load duration curve?

When the load elements of a load curve are arranged in the order of dending magnitudes, the curve thus obtained is called load duration curve.

The load curve is obtained from the same data as the load curve but the ordinates are arranged in the order of dending magnitudes. In other words, the maximum load is represented to the left and decreasing loads are represented to the right in the dending order. Hence the area under the load duration curve and the load curve are equal.

Load factor and diversity factor play a vital role in the cost of the supply of electrical energy. Higher the values of load factor and diversity factor, lower will be the overall cost per unit generated.

8) Write the significance of load factor?

Higher load factor means greater average load, resulting in greater number of units generated for a given maximum demand. Thus, the standing charges, which are proportional to maximum demand and independent of number of units generated, can be distributed over a large number of units supplied and therefore overall cost per unit of electrical energy generated will be reduced.

9) What is mean by base load?

The unvarying load which occurs almost the whole day on the station is known as base load. 10) What are the methods for determining depreciation charges?

The decrease in the value of the power plant equipment and building due to constant use is known as depreciation. The cost of depreciation will depend on the size and type of equipment and on its estimated life.

The reduction in the value of the plant every year is known as annual depreciation. Due to depreciation the plant has to be replaced by new one after its useful life. Therefore a suitable amount must be set aside every year, so that by the time the plant retires the collected amount by way of depreciation equals the cost of equipment.

The methods commonly used for determination of annual depreciation charges are

- Straight line method
- Diminishing value method and
- Sinking fund method.

11) What are the objectives of tariff?

Electrical energy is sold at such a rate so that it not only returns the cost but also earns reasonable profit. Therefore, a tariff must cover the following items:

- Recovery of cost of capital investment in generating, transmitting and distributing equipment.
- Recovery of cost of operation, supplies and maintenance of equipment.
- Recovery of cost of metering equipment, billing, and collection costs etc.
- A satisfactory return on the total capital investment.

12) Define energy audit.

Energy Audit means studying the energy consumption patternin the utilities or equipments by obtaining necessary data analyse the same to identify the areas where wastages or loses occur and suggest methods to avoid wastages or loss and also other consumption measures to ensure efficient use of energy.

13) What are the causes of low power factor?

The following are the causes of low power factor

- Most of the a.c motors are of induction type which have low lagging power factor. These motors work at a power factor which is extremely small on light load 0.2 to 0.3 and rises to 0.8 to 0.9 at full load.
- Arc lamps, electric discharges lamps and industrial heating furnaces operate at low lagging power factor.
- The load on the power system is varying, being high during morning and evening and low at other times. During low load period, supply voltage is increased which increases the magnetization current. This results in the decreased power factor.

14) Define the term connected load factor.

It is the sum of the continuous rating in KW of all electrical devices installed at the consumer’s premises and connected to the supply system.

15) What are the important points to be taken into consideration while selecting the size and number of units?

- The load on a power station is never constant due to variable demands from time to time. The nature of these demands can be seen from the load curve. The load variation is greater with a poorer load factor.
- The selection of the number and sizes of the units is per decided from the annual load curve of the station. The number and size of the units are selected in such a way that they correctly fit the station load curve.

The capacity of the plant should be made 15% to 20% more than the maximum demand to meet the future load requirements. There should be a spare generating unit so that repairs and overhauling of the working units can be carried out.

16) Define capacity factor.

It is the ratio of average demand to plant capacity 17) What is plant use factor?

It is defined as the ratio of kwh generated to the product of plant capacity and number of hours for which the plant is in operation.

18) What are the important types of power factor tariff?

(i) KVA maximum demand tariff
(ii) Sliding rate tariff
(iii) KWh and kVAR tariff

19) What is three part tariff?

The total charge comprised of fixed charge made during billing period, charge per kW of maximum demand and charge per kWh of energy consumed.

20) What is the difference between base load and peak load?

- The unvarying load which occurs almost thewhole day is known as base load.
- The various demands of load over and above the base load is the peak load.

UNIT-III
ILLUMINATION, HEATING AND WELDING

1) Define luminous flux.

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. The conception of luminous flux helps us to specify the output and efficiency of a given light source.

2) What is meant by candle power?

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

$$CP = lumens/\omega$$

3) Define MHCP.

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

4) Define utilization factor.

It is defined as the ratio of total lumens reaching the working plane to total lumens given out by the lamp.

Utilization factor= Total lumens reaching the working plane/Total lumens given out by the lamp

5) What are the laws of illumination?

Law of Inverse Squares:

Illumination at appoint is inversely 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 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.

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.

6) What is meant by luminance?

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

7) Define space-height ratio.

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

Space-height ratio= Horizontal distance between two adjacent lamps/Mounting height of lamps above working plane

8) What is polar curve?

In most lamps or sources of light the luminous intensity is not the same in all directions. If the luminous intensity, i.e. the candle power is measured in a horizontal plane about a vertical axis and a curve is plotted between candle power and the angular position,a curve is obtained is called as horizontal polar curve.

The luminous intensity in all the directions can be represented by polar curves. If the luminous intensity in a vertical plane is plotted against the angular position, a curve known as vertical polar curve is obtained.

9) Name the various photometer heads.

1. Bunsen Head (or) Grease spot photometer
2. Lummer-Brodhun photometer head

a) Equality of Brightness type photometer head
b) Contrast type photometer head

10) What are all the sources of light?

According to principle of operation the light sources may be grouped as follows.

- Arc lamps
- High temperature lamps
- Gaseous discharge lamps
- Fluorent type lamps

11) What is stroboscopic effect of fluorent 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.

12) Define beam factor.

The ratio of lumens in the beam of a projector to the lumens given out by lamps is called the beam factor. This factor takes into account the absorption of light by reflector and front glass of the projector lamp. Its values vary from 0.3 to 0.6.

13) Mention the types of lighting schemes.

The distribution of the light emitted by lamps is usually controlled to some extent by means of reflectors and translucent diffusing screens or even lenses. The interior lighting schemes may be classified as

- Direct lighting
- Semi-direct lighting
- Indirect lighting
- Semi-indirect lighting
- General lighting

14) What are the drawbacks of discharge lamps?

Drawbacks of discharge lamps:

- Take time to attain full brightness.
- High initial cost and poor power
- factor. Starting requires trigger-starter.
- Light output fluctuates at twice the supply
- frequency. The flicker causes stroboscopic effect.
- These lamps can be used only in particular position.

15) What are the requirements of lighting system?

The following factors are required to be considered while designing the lighting scheme.

- Illumination level
- Uniformity of illumination

- Colour of light
- Shadows
- Glare
- Mounting height
- Spacing of luminaries
- Colour of surrounding walls.

16) What are the advantages of electric heating?

The main advantages of electric heating over other systems of heating such as coal, oil or gas heating are given below.

- Economical
- Cleanliness
- Absence of flue gases
- Ease of control or adaptation
- Automatic protection
- Upper limit of temperature
- Special heating features
- High efficiency of utilisation
- Better working conditions
- Safety
- Heating of non-conducting materials

17) Classify the methods of electric heating.

Kids of electric heating

A. Power frequency heating

a. Resistance heating

i) Direct resistance heating

ii) Indirect resistance heating

iii) Infrared or Radiant heating

b. Arc heating

i) Direct arc heating

ii) Indirect arc heating

B. High frequency heating

a. Induction heating

i) Direct induction heating

ii) Indirect induction heating

b. Dielectric heating

18) What is meant by indirect resistance heating?

In this method, the current is passed through a high resistance wire known as heating element. The heat produced due to I2 R 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.

19).What is meant by (1) infra red /radiant heating? (2) Dielectric heating?

(1)When current possess through a resistive element heat energyis produced and the same is dissipated in the form of infrared radiation this is focused upon a body to be heated .e.g. to dry the wet paint on an object.

(2)When a non metallic material is placed between two electrodes at high voltage the dielectric loss is dissipated in the form of heat which is used for heating purposes.

20) What are the requirements of a good heating material?

1. High ressistivity
2. Low temperature coefficient of ressistance
3. High melting point
4. Free from oxidation

21) What are the properties of heating element material?

- The material of the heating elements should posses the following desirable properties for efficient operation and long life.
- High resistivity: It should have high specific resistance so that the overall length to produce a certain amount of heat may be smaller.
- High melting point: It should have high melting point so that high temperatures can be produced without jeopardizing the life of the element.
- Free from oxidation: It should be able to resist oxidation at high temperatures; otherwise its life will be shortened.
- Low temperature coefficient: It should have a low temperature coefficient so that resistance remains appreciably constant even with increases of temperature. This helps in accurate control of temperature.

22) What are the causes of failure of heating elements?

Principle causes are

- Formation of hot spots
- General oxidation of the element and intermittency of operation
- Embrittlement caused by grain growth
- Contamination of element or corrosion

23) Write short note on infrared 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 up to 7500 watts/sq.m can be obtained leading to heat absorption up to 4300 watts/sq.m. This reduces the time taken by various drying process.

24) What is the basic principle of induction heating?

High frequency eddy current heating produced by eddy currents induced by electromagnetic action in the metal to be heated.It works on the principle of electromagnetic induction as same as a transformer. It has a metal disc surrounded by a copper coil in which a.c supply is flowing. The disc has a finite value of diameter and thickness and is spaced a given distance from the coil and concentric to it. We find that a secondary current is caused to circulate around the outer surface of the disc.

25) What are the different types of resistance welding?

The different types are as follows

- Butt welding Spot
- welding Projection
- welding Seam
- welding Percussion
- welding

26) Compare DC welding and AC welding.

Sl.no	Factors	D.C welding	A.C welding
1.	Equipment	Motor-generator set or rectifier is required in case of availability of a supply; otherwise oil generator set is required.	Only a transformer is required.
2.	Prime Cost	Two or three times of transformer.	Comparatively low
3.	Operating efficiency	Low	High 85%
4.	No-Load voltage	Low	Too high
5.	Power factor	High	Low
6.	Heating	Uniform heating	Non-uniform heating
7.	Arc stability	Higher	-
8.	Arc blow	Pronounced	Not so pronounced

27) What is LASER welding?

LASER (Light Amplification by Stimulated Emission of Radiation) welding is a welding process that uses the heat from a laser beam impinging on the joint. The process is without a shielding gas and pressure.

UNIT-IV
INDUSTRIAL HEATING AND WELDING

1. State the advantages of electric
   - heating. Cleanliness
   - Economical
   - Uniform heating
   - Cheap furnace
2. What are the modes of heat
   - transfer? Conduction
   - Convection
   - Radiation
3. State Stephan's law of radiation

   In this process heat is transferred by means of heat waves governed by Stephan's law
4. What are the properties of heating element material?
   - High specific resistance ---- free from oxidation
   - High melting point -----------small temp coefficient
5. Name the method of temp control in resistance oven.
   - By varying the no. of elements
   - Changing in connection

- External series resistance
- Changing transformer tappings
- Automatic control

6. How electric heating is classified?
   - Resistance heating
   - Induction heating
7. What are the applications of induction
   - heating? Surface hardening
   - Annealing
   - Melting
   - Tempering
   - Soldering
8. Mention few draw backs of core type furnace.
   - Due to poor magnetic coupling, leakage reactance is high and power factor is low
   - Low frequency supply is required
9. State the advantage of core less induction furnace
   - Time taken to reach the melting temp is less
   - There is no smoke and noise
10. What is induction heating?
    - Induction heating is a method of providing fast & consistent heating for manufacturing applications which involved bonding or changing properties of metlal for electrically conducting materials.
    - Todays advanced design concepts warrant most engineering components to be heated to either from different shapes or attain specific grain structures.
    - Microtech's range of induction heating systems are offered for custom built applications with suitable coils, materials handling solutions with complete automation
11. What are the classifications of power frequency method?
    - Direct resistance heating
    - Indirect resistance heating
    - Direct arc heating
    - Indirect arc heating
12. What is meant by direct resistance heating?

In this method opf heating current is passed through the body to be heated.the resistance offered by the body to the flow of current produces ohmic loss which results in heating the body.

13. What is meant by indirect resistance heating?

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

14. What is the requirement of a good heating material?
    - High specific resistance
    - High melting point
    - Free from oxidation
    - Low temperature co efficient of resistance
15. What are the properties of steel?
    1. Strength - the ability to withstand mechanical stress
    2. Ductility - Ability to be formed without rupture
    3. Hardness - Resistance to deformation, abrasion, cutting, crushing

4. Toughness - ability to absorb shock without breaking

16. What is annealing in heat treatment?

Annealing consists of heating the steel to or near the critical temperature (Temperature at which crystalline phase change occurs) to make it suitable for fabrication. Annealing is performed to soften steel after cold rolling, before surface coating and rolling, after drawing wired rod or cold drawing seamless tube. Stainless steels and high alloy steels generally require annealing because these steels are more resistant to rolling.

17. What is normalizing?

Normalizing consists of heating the steel above the critical temperature and cooling in air. This treatment refines the grain size and improves the uniformity of microstructure and properties of hot rolled steel. Normalizing is used in some plate mills, in the production of large forgings such as railroad wheels and axles, some bar products.

18. What is quenching?

Quenching consists of heating the steel above the critical point and holding at that temperature for enough time to change the crystalline structure. This heat is followed by quenching in a water or oil bath to bring the steel back through the critical temperature range without further changes to the microstructure. Quenching produces very hard, very brittle steel.

19. What is tempering?

Tempering is carried out by preheating previously quenched or normalized steel to a temperature below the critical range, holding, and then cooling to obtain the desired mechanical properties. Tempering is used to reduce the brittleness of quenched steel.Many products that require hardness and resistance to breakage are quenched and tempered.

20. What is dielectric heating?

The process of heating poor conductors of electricity (dielectrics) by- means of high-frequency electrical currents. The thermoplastic composite to be heated forms the dielectric of a condenser to which is applied a high-frequency (20-to-80 mc) voltage.The heat is developed within the material rather than being brought to it from the outside, and hence the material is heated more uniformly throughout.

UNIT-V
ELECTRIC TRACTION

1) What are the requirements of an ideal traction system?

The requirements of an ideal traction system are as follows

- The starting tractive effort should be high so as to have rapid
- acceleration. The wear on the track should be minimum.
- Pollution free
- Speed control should be easy.
- The equipment should be capable of withstanding large temporary loads.
- Low initial and maintenance cost.
- There should be no interference to the communication lines running along the
- lines. Braking should be such that minimum wear is caused on the brake shoes.

2) Name the various systems of traction.

1. Direct steam engine drive
2. Direct Internal Combustion Engine Drive
3. Steam Electric Drive
4. Internal Combustion Engine Electric Drive

5. Petrol Electric traction
6. Battery Electric Drive
7. Electric Drive

3) Classify the supply system for electric traction.
A. D.C system
B. A.C system
i) Single phase
ii) Three phase
C. Composite system
i) Single phase AC-DC
ii) Single phase-Three phase

4) What are the advantages of electric traction?
- High starting torque
- Less maintenance cost
- Cheapest method of traction
- Rapid acceleration and
- braking Less vibration
- Coefficient of adhesion is better
- It has great passenger carrying capacity at higher speed.

5) What are the disadvantages of electric traction?
- High capital cost
- Problem of supply failure
- Additional equipment is required for achieving electric braking and control
- The leakage of current from the distribution mains and drop of volts in the track are to be kept within the prescribed limits.

The electrically operated vehicles have to move on guided track only.

6) Define average speed and scheduled speed.

Average speed is the ratio of distance between two consecutive stations to time taken to travel the distance; Scheduled speed is the ratio of distance between two consecutive stations to total time taken for moving including the time for stops.

7).Name the different stages of train movement
1. Acceleration
2. Constant speed or free running
3. Coasting, running with power switched off and brake not applied
4. Retardation, with braking

8) What are the essential features (electrical) of an ideal traction motor?
1. High starting torque.
2. Series speed torque characteristics
3. Simple speed control
4. Possibility of regenerative braking

9) What is the need for traction motor control?
1. To limit starting current
2. Smooth acceleration without jerk
3. Both manual and automatic control should be possible.

10) What is meant by speed-time curve? Why it is used?

The movement of the train and their energy consumption can be studied by means of speed-time and speed-distance curves, which shows the speed at different time instants after start of run and speed at different distances from the starting point respectively. Of the two, the speed-time curve is generally used.The curve drawn between speed in Kw/hr along Y-axis and time in seconds along X-axis is called speed=time curve. The speedtime curve gives the complete information about the motion of the train.

This curve gives the speed at various time instants after the start of run directly. Slope of the curve at any point gives the speed at that instant. The area under the curve gives the total distance traveled by the train.

11) What do you mean by average speed in electric traction?

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

Average speed= Distance between stops in km/Actual time of run in hours

12) What do you mean by schedule speed in electric traction?

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

Schedule speed = Distance between stops in km/Actual time of run in hours+ Stop time in hours The schedule speed is always smaller than the average speed.

The difference is large in case of urban and suburban services and is negligibly small in case of main line service.

13) What is tractive effort?

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

Total tractive effort required to run a train on track= Tractive effort to produce acceleration + Tractive effort to overcome effect of gravity + Tractive effort to overcome train resistance.

14) What are the factors affecting energy consumption?

The various factors affecting energy consumption are

(i) Distance between the stops

The greater the distance between the stops, the lesser will be the specific energy consumption for suburban service is 50 to 75 watts-hour/ ton-km and for main line service it is between 18 to 32 Watt-hour/ton-km.

(ii) Train resistance

The train resistance depends upon the nature of track, speed of the train and shape of the rolling stock, particularly the front and rear portions of the train. If the train resistance is greater, the specific energy consumption is more.

(iii) Acceleration and retardation

If the acceleration and retardation increases, the specific energy consumption is increased.

(iv) Gradient

The steep gradients will involve more energy consumption though regenerative braking is applied.

(v) Train equipment

More efficient train equipment will reduce the specific energy consumption.

15) Define dead weight, adhesive weight.

(i) Dead weight

The total weight of locomotive and train to be pulled by the locomotive is known as dead weight.

(ii) Adhesive weight

The total weight to be carried on the driving wheels is known as the adhesive weight.

16) Name the various methods of traction motor control.

There are various methods for controlling the speed of d.c series motors. They are

*Rheostatic control
*Series parallel control
*Field control
*Buck and Boost method
*Metadyne control
*Thyristor control

17) What are the basic requirements of braking system?

The basic requirements of a braking system are given below

- It should be simple, robust, quick and reliable in action.
- Easy to use for driver to operate.
- Maintenance should be minimum.
- The braking system should be inexhaustible.
- In case of emergency braking, safety consideration is taken into account.
- Kinetic energy of the train must be storable during braking which could be used subsequently during acceleration of the train.

18) What are the various methods of applying electric braking?

There are three methods of applying electric braking are

- Plugging or Reverse current braking
- Rheostatic braking Regenerative
- braking.

19) Name the advanced methods of speed control of traction motors.

The latest methods of speed control of traction motors are

- Tap changer control
- Thyristor control
- Chopper control
- Microprocessor control

20) What are the advantages of microprocessor based control of traction motors?

The advantages of microprocessor based drives are

- High speed of response
- High accuracy
- Over voltage and over speed protection.
- Electronic interlocking
- Less sensitive to temperature variations and drift.
- Numbers of components used are less.

Question Paper Code : 51452

B.E./B.Tech. DEGREE EXAMINATION, APRIL 2014.

Eighth Semester

Electrical and Electronics Engineering

EE 2451/EE 81/10133 EE 801 — ELECTRIC ENERGY GENERATION, UTILIZATION AND CONSERVATION

(Regulation 2008)

Time : Three hours | Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What are the essential components of nuclear reactor?

2. How tides are caused? What are the types of tides?

3. What are the components of fixed cost and running cost?

4. Name some energy efficient equipments.

5. Define Lumen.

6. List the types of lamps.

7. What are the requirements of a good heating material?

8. What is meant by electric arc welding? What are the different types of electrode used and its applicability?

9. Give the expression for total tractive effort.

10. What are the recent trends in electric traction?

PART B — (5 × 16 = 80 marks)

11. (a) (i) Explain the layout of Hydro power plant. (10)

(ii) Classify Hydro plants based on operation. (6)

Or

(b) (i) Schematically describe the residential cooling and heating with solar energy. (10)

(ii) Explain flat plate collector. (6)

12. (a) (i) Explain the Load Duration curve with example. (8)

(ii) A system has a straight line annual load duration curve with maximum and minimum demands of 15 MW and 5 MW respectively. The annual cost characteristics of base load and peak load stations are respectively given by,

$$C_1 = (\text{Rs. } 100000 + \text{Rs. } 100/\text{KW} + 6\ \text{P/KWhr})$$

$$C_2 = (\text{Rs. } 80000 + \text{Rs. } 60/\text{KW} + 8\ \text{P/KWhr})$$

Determine the operating schedule of peak load station for minimum annual cost. Hence determine the overall cost per KWhr. (8)

Or

(b) (i) Write a brief note on power factor improvement by power capacitors. (8)

(ii) Explain the Energy Audit Methodology. (8)

13. (a) Explain the working of a high pressure mercury vapour lamp with a neat sketch. (16)

Or

(b) (i) Explain Flood lighting with necessary definitions. (8)

(ii) State and explain laws of illumination. (8)

14. (a) (i) Explain Induction heating. What are the Characteristics of Induction heating? Explain Ajax-Wyatt Furnace. (10)

(ii) Determine the efficiency of a high frequency induction furnace which takes 10 minutes to melt 1.815 Kg of aluminium the input to the furnace being 5 KW and the initial temperature 15 degree centigrade,

Specific heat of aluminium – 0.212 K Cal/kg°C

Melting point – 660 degree centigrade

Latent heat of fusion of aluminium = 76.8 K Cal/Kg. (6)

Or

(b) (i) Illustrate the basic principle of Resistance welding. Also discuss Spot welding and Butt welding. (11)

(ii) Differentiate AC welding and DC welding. (5)

15. (a) (i) State the advantages and disadvantages of electric traction. (7)

(ii) State the requirements of an ideal traction system. (6)

(iii) List the various sources for Electric traction. (3)

Or

(b) (i) List the requirements of electric traction system. (8)

(ii) Explain the D.C series Traction motor control. (8)

Question Paper Code: 11380
B.E./B.Tech. DEGREE EXAMINATION. NOVEMBER, DECEMBER 2012.
Ejghth Semester
Electrical and Electronics Engrneering
(Regulation 2008)

Time: Three hours Maximum: 100 marks

Alswer ALL questions
PARTA-(10x2-20marks)

1. Wlat is the use of super heater in steam power plant?
2. Define the term gust in wind energy system.
3. Differentiate between load curve and load duration curve.
4. State any two steps taken fol power quality improvement-
5. Define luminous efficacy.
6. What is the importance of strect lighting system?
7. Give the methods of control oftemperature in arc lurDaces.
8. List some steps taken to minimize skin effect in induction heating.
I9.Define crest speed of a train.
10. Wlat are the requirements for an electdc traction system?

PART B (5 x 16 = 80 marks)

11. (a) (i) Dcscribe with neat sketch the construciion and principle of operation of a hydel power plant. (10)
(ii) Explain in detail about the reactor system in a nuclear power plant. (6)
(b) (i) Explain with neat diagram the power generation from geothermal plant. (10)
(ii) List ihe prospects of distributed generation system. (6)

12. (a) The load on a power plant on a typical day is given below :

Time :	12–5 A.M.	5–9	9–6	6–10	10 P.M. – 12 A.M.
Load in MW :	20	40	80	100	20

Plot the load duration curve. Firld the load lactor of the plant and the energy supplied by the plant in 24 hours- Also suggest the size and number of generating units. (16) Or

(b) (i) Explain the reasons why power factor tariff is imposed. Explain clearly the procedure for finding out the capacity of the shunt ciapacitor required for an existing installation for improvement of power factor. (10)

13. (a) (i) Discuss laws ofillumination and its limitation in actual practice. (8)
(ii)A lamp of 500 cp is placed 2m below a plane miuor which reflects 80% of light falling on it. Determine illumination at a point 5 m away ftom the foot ofthe lamp which is hung 5 m above the ground. (10)

Or

(b) (i) Describe the construction and pinciple of operation of mercury Yapour lamp- (8)
(ii) Explain the vadous factors to be taken into account for designing street lighting and flood Lighting. (8)

14. (a). (i) Explain the working of coreless induction furnace and list its medts. (6)
(ii) Calculate the time taken to melt 3 nietdc tones of steel in a three phase arc furnace having the following data:
Current = 5000 A; Arc voltage = 60 V
Resistance of transformer = 0.003 ohms; Reactance of transformer = 0.005 ohms;

Melting point ofsteel = 1370' C; Initial temperature of steel = 18' C. Assume overall efficiencv as 60%. (10)

Or

(b) (i) Explarn the vadous tlTes ofelectdc arc welding. (8)

(ii) Explain the principle and working ofwelding transformer. (8)

15. (a) (i) List the medts of electdc traction compare with conventional system. (6)

(ii) A 250 tonnes train with 10% rotatioDal inertia effect is started with uniform acceleration and reaches a speed of 50 kmphps in 265 seconds on level road- Find the specific energy consumption if the journpy is l,o be made ac.ording ro rrapezoialal speed - lrmg qu11g. Acceleration = 2 kmphps; Tracking retardation = 3 kmphps; Distance betvreen the stations is 2.4 km; Efficiencv = 0.9; Track resistance = 5 kg/tones. (10)

Or

(b) (i) Defrne specific energy consumption and discuss the factors that affects the specfic energy consumption of trains operation at a given schedule speed. (8)

(ii) Explain regenerative braking when used for dc series traction motors- How does it differ foom the regenerative braking as used for shunt motors? (8)

Question Paper Code: D 221-!

B.E.iB.Tech. DEGREE EXAMINATiON, APRIL/MAY 2010.

Eighth Semester

Electrical and Electronics Engineering

EE 1451 - ELECTRIC ENERGY GENERATION, UTILISATION AND CONSERVATION

(Regulation 2004)

1. Give the principle of working of geothennal power generation.
2. State the advantages of MHD power generation.
3. Give any four objectives of tariff.
4. Defrne the term power quality.
5. State the laws of illumination.
6. What are the properties heating element matenals?
7. What ilrpe of notor is used for electric traction? Why?
8. Give any two advantages of electric traction.
9. Dehne continuous rating of rnotor.
10. Why is induction rnotor cornrnonly preffered drive for industriai application?

PART B (5* 16 = 80 marks)

11. (a) With a neat block diagram explain the main parts and workrng of a wind electric system. (16)

Or

(b) (i) Write a note on distributed generation. (8)

(ii) Explain the main components and working of Tidal power plant. (8)

12. (a) Write short notes on:

(i) Need for electrical energy conservation (6)

(ii) Energy management (5)

(iii) Energy auditing (5)

Or

(b) Explain the different methods of power factor improvement. (16)

13. (a) (i) With oecessary equations describe the design of heating element. (10)

(ii) Write about welding transformer and its characteristics. (6)

Or

(b)(i) Discuss the various steps involved in the design of illumination system. (8)

(ii) Discuss the various aspects of residential lighting and street lighting. (8)

14. (a)(i) Discuss the recent trends in electric tractron. (8)

(ii) Descrlbe the different types of supply systems used for railway electrification. (8)

(b) (i) Write about mechanics of train movement. (8)

(ii) Discuss the working of D C selies motor controi in detail. (8)

15. (a) Explain state state and transient characteristics of.drives. (16)

Or

(b) What do you understand by the term load equahzation? Derive the expression lor moror torque in case of motor fitted with the flywheel when load is increasing. (16)

B.E./BTech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2008.
Eighth Semester
(Regulations 2004)
Electrical and Electronics Engineering
EE 1451 - ELECTRIC ENERGY GENERATION UTILIZATION AND CONSERVATION

1. Give four sources of non-conventional energy.
2. Name the various semi conductors used for photovoltaic conversion.
3. Define load factor.
4. What are the causes of low power factor?
5. Define the term Lux.
6. List the four merits of electrically produced heat.
7. Define tractive effort.
8. What is neant by specific energy consumption?
9. What are the advantages of individual drive?
10. What type of electrical drive is used in (a) Cranes (b) Blowers?

PARTB-(5x16=80marks)

11. (a) (i)What are the basic components of solar pv system?(8)
(ii)Explain the basic solar PV system used fof power generation.(8)

(b) Give a brief review of ger-reration of electrical Power by any two conventiorral methods (8+8)

12. (a) The maximum demand of power plant is 40 MW. The capacity factor is 0.5 and the utilisation factor is 0.8. Find

(i) Load factor

(ii) Plant capacity factor

(iii) Reserve capacity. (6 + 6 + 4)

Or

(b) Discuss the following types of tariffs :

(i) Two part tariff

(ii) Three part tariff

(iii) Flat demand tariff

(iv) Straight meter rate tariff. (4 × 4 = 16)

13. (a) A 30 KW, three phase, 400 V over is to employ nickel-chrome strip 0.254 mm thick for the three star-connected heating elements. If the wire temperature is to be 1100°C and that of charge to be 700°C. Estimate a suitable width for the strip. Assume conductivity of 0.9 and radiating efficiency to be 0.5. What would be the temperature of the wire if the charge were cold? (16)

Or

(b) (i) Explain the working of low pressure mercury vapour lamp with necessary circuit diagram. (8)

(ii) Two street lamps are 20 m apart and fitted with a 500 C.P. lamp at a height of 8 m above the ground. Find the illumination at a point under the lamp post and midway between the lamps. (8)

14. (a) A train runs at an average speed of 45 km per hour between stations 2.5 km apart. The train accelerated at 2 kmphps and retards at 3 kmphps. Find its crest speed assuming trapezoidal speed time curve. Calculate also the distance travelled before the brakes were applied. (16)

Or

(b) (i) What are the merits of electric braking? (6)

(ii) Describe briefly about regenerative braking and how this can be applied to D.C. series traction motors. (10)

15. (a) Explain the different factors to be considered for selection of electric drives for a specific application. (16)

Or

(b) A 200 V, 875 rpm, 150 A d.c. motor has an armature resistance of $0.06\,\Omega$. It is fed from a single phase fully controlled rectifier with an A.C. source voltage of 220 V, 50 HZ. Calculate the firing angle for rated motor torque at 750 r.p.m. (16)

B.E./B.Tech. DEGREE EXAMINATION, APRIL/MAY 2008.

Eighth Semester

(Regulations 2004)

Electrical and Electronics Engineering

EE 1451 — ELECTRIC ENERGY GENERATION UTILIZATION AND CONSERVATION

(Common to B.E. (Part-Time) Seventh Semester Regulation 2005)

Time : Three hours   Maximum : 100 marks

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. Give any two reasons to go for non conventional sources for power generation.

2. Draw a typical daily load curve.

3. What is meant by geothermal energy?

4. State the advantages of power factor improvement.

5. What are the properties of heating materials?

6. State the laws of illumination.

7. Explain the terms dead weight and adhesive weight as applied to a locomotive.

8. What is scheduled speed of a train?

9. What is load equalization?

10. Distinguish between individual drive and group drive.

PART B — (5 × 16 = 80 marks)

11. (a) Explain in detail about the electric energy generation by tidal power and wind power. (16)

Or

(b) Write about the concept of distributed generation and its effect on system operation. (16)

12. (a) (i) Write a short note on the need for energy conservation. (8)

(ii) Discuss briefly about energy auditing. (8)

Or

(b) (i) Discuss the various methods to improve power-factor. (8)

(ii) Define power quality and explain related terms. (8)

13. (a) (i) With a neat diagram explain the working of High pressure sodium vapour lamp. (8)

(ii) A lamp of 500 c.p. is placed at the centre of a room $(20 \times 10 \times 5)$ m^3. Calculate illumination in each corner of the room. (8)

Or

(b) (i) Derive the expressions for distance 'd' and length 'l' of a heating element. (8)

(ii) Explain construction and operating principle of welding transformer and its characteristics. (8)

14. (a) (i) Explain different methods of traction motor control. (10)

(ii) Write in detail about mechanics of train movement. (6)

Or

(b) Describe in detail the recent trends available in electric traction system. (16)

15. (a) Mention the criteria to be considered while selecting a motor for a specific application. Explain with example. (16)

Or

(b) Discuss various methods of speed control of industrial drives. Write typical examples for each drives. (16)

GLOSSARY

Anaerobic – living in the absence of air or free oxygen, or a chemical reaction or process not dependent on the presence of oxygen.

Ballast – part of a fluorent light fixture that supplies initial electricity to the bulb and regulates electricity flow

Battery – device that stores energy and furnishes electric current upon demand

Bio-diesel – a blend of bio-fuel and petroleum diesel which can be used in compression-ignition (diesel) engines

Bio-fuel – fuel produced from plant and organic-based compounds.

Biogenic – resulting from the activity of living organisms, as fermentation; produced by living organisms or biological processes.

Biomass – a renewable energy source derived from organic materials including plant matter and animal waste that is usually incinerated to produce electricity

British thermal units (Btu) – a unit of energy equal to the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit at one atmospheric pressure.

Carbon Dioxide (CO2) – a compound carbon and oxygen generated as a by-product of the combustion of fossil fuels or the burning of vegetable matter; is an acidic oxide; toxic in high concentrations.

Carbon monoxide (CO) – an odorless, colorless and toxic gas that results from incomplete oxidation of carbon in combustion; burns with a violet flame

Commissioning – quality-oriented process for achieving, verifying, and documenting that the performance of facilities, systems, and assemblies meets defined objectives and criteria

Compressed natural gas (CNG) – a natural gas that is under pressure, remains clear, odorless and non-corrosive and is often used as an environmentally friendly substitute for gasoline or diesel

Condenser coils – soft aluminum tubes in an HVAC unit through which refrigerant flows so it can be cooled, allowing for the transfer of heat more quickly

Conservation – the careful utilization of natural resources in order to prevent depletion (see also energy conservation)

Cool Roofs – roofs consisting of materials that very effectively reflect the sun's heat energy from the roof surface.

Demand Response Program – Demand response (also known as load response) is end-use customers reducing their use of electricity in response to power grid needs, economic signals from a competitive wholesale market or special retail rates.

Direct Current (DC) – electricity that flows in one direction steadily with constant strength, not used for long-distance power transmission

Economizer – mechanical devices intended to reduce energy consumption in buildings by recapturing heat from the building before air is exhausted to the outside or by using ambient air temperature outside to adjust building temperatures inside without requiring mechanical heating or cooling.

Fossil fuel – fuels such as oil, natural gas and coal that were naturally produced over long periods of time from the remains of living organisms.

Efficiency – a relative measure of the amount of energy required to do a task compared to the optimum means of accomplishing the same task.

Ethylene propylene diene monomer (EPDM) – high-density synthetic rubber used as a roofing material that is very durable, has great resistance to abrasives, tearing, solvents and high temperatures

Electric Vehicle (EV) – a vehicle propelled by an electric motor(s) powered by battery packs that can be recharged by plugging them into a power outlet.

Emissions – substances discharged into the air including by-products of internal combustion engines and power generating plants that are fired by coal, natural gas or oil.
Energy – (physics) a thermodynamic quantity equivalent to the capacity of a physical system to do work;
Energy conservation – is the practice of decreasing the quantity of energy used. It may be chieved through more efficient energy use, in which case energy use is decreased
while achieving a similar outcome (e.g. improving insulation in exterior walls), or by a reduction in activities that consume energy (e.g. turning off lights when not in the room).
Energy Star – A joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy developed to protect the environment through energy efficiency products and practices.
Ethanol – a liquid fuel produced through man-made processing of organic matter;
Flex Fuel Vehicle (FFV) – a vehicle designed to run on both gasoline and a blend of gasoline and ethanol; FFVs typically get about 20-30 percent fewer miles per gallon since ethanol contains less energy than gasoline
Fluorent lights – lights where the source of light is produced by gas that glows when connected to electricity. Fluorent light bulbs can have a very long life – between 8,000 and 20,000 hours. They use up to 75 percent less power than incandent light bulbs.
Fuel cell – a device used for combining fuel and oxides to generate electricity. It is the conversion of chemicals to electrical energy.
Geothermal – refers to the utilization of the relatively constant below-grade temperatures of the earth for either heat extraction or heat rejection for HVAC systems in buildings.
Greenhouse gases (GHG) – any gas that absorbs infrared radiation in the atmosphere; includes water vapor, carbon dioxide (CO2), methane (CH4), nitrous oxide (N20), halogenated fluorocarbons (HCFCs), ozone (O3), perfluorinated carbons (PFCs) and hydrofluorocarbons HFCs)
Heat pump – a machine or device that moves heat from one location (the 'source') to another location (the 'sink' or 'heat sink') using mechanical work. One common type of heat pump works by exploiting the physical properties of an evaporating and condensing fluid known as a refrigerant. Common examples are food refrigerators and freezers, air conditioners, and reversible-cycle heat pumps for providing thermal comfort.
Hybrid Electric Vehicle (HVE) – a vehicle propelled by an internal combustion engine and an electric motor(s);, the HVE converts energy normally wasted during coasting and braking into electricity, which is stored in the battery until needed by the electric motor.
Hydrocarbons (HC) – organic compounds that contain only carbon and hydrogen
Hydroelectricity – electricity generated from the power of moving water operating electrical turbines
Hydrogen – the most abundant element on earth yet hydrogen does not occur naturally; once separated from another element, hydrogen can be burned as a fuel or converted into electricity.
Improving energy efficiency – accomplishing a task with less energy; energy efficiency may be improved by changing-out older technology equipment with newer technology equipment (for example replacing 32-watt light fluorent bulbs with 28-watt bulbs which produce equal light).
Incandent light – lights where the source of the light is an electric current passing through a thin filament, heating it until it glows
Kilowatt hour (kWh) – measure of electricity equal to 1 kilowatt of power produced or used over 1 hour
Landfill Gas to Energy (LFG) – A process of burning the gases produced by decomposing waste in landfills to power electric generators

Leadership in Energy & Environmental Design (LEED) – A rating scale developed by the U.S. Green Building Council for measuring a building's impact on the environment and those that will occupy the building;
Light Emitting Diode (LED) – a light source that uses significantly less energy than traditional lighting because it produces light without significant waste heat
Maryland Renewable Portfolio Standard (RPS) – a Maryland statute that requires electricity suppliers (all utilities and competitive retail suppliers) to use renewable energy sources to generate a minimum portion of their retail sales. Beginning in 2006, electricity suppliers are required to provide 1% of retail electricity sales in the state from Tier 1 renewables and 2.5% from Tier 2 renewables. The renewable requirement increases gradually, ultimately reaching a level of 20% from Tier 1 resources in 2022 and beyond, and 2.5% from Tier 2 resources from 2006 through 2018. The Tier 2 requirement sunsets, dropping to 0% in 2019 and beyond **Megawatt (MW) –** unit of energy equal to 1 million watts or 1,000 kilowatts
Methane (CH4) – odorless, colorless, flammable gas, released during decomposition of plant or other organic compounds; main component of marsh gas and frequently formed in coal mines; used as a source of fuel and an important source of hydrogen
Million Metric Tons of Carbon Equivalent (MMTCE) – also referred to as carbon equivalent. Metric measure used to compare the emissions of greenhouse gases based upon their global warming potential. The equivalent for gas is derived by multiplying the tons of gas by the associated global warming potential.
Natural gas – a fossil fuel that is a colorless and odorless gas **Non-renewable energy**– of or relating to energy sources such as oil, natural gas, coal, uranium that are not replenishable, or that are produced naturally at a dramatically slower rate than current demand would utilize.

Northeast Maryland Waste Disposal Authority (NMWDA) – An independent State agency representing 7 Maryland counties and the City of Baltimore
Oxygenated fuel – fuel that has a chemical compound containing oxygen added to improve combustion efficiency and reduce some types of atmospheric pollution **Photovoltaic (PV)** – direct conversion of light into electricity through solar cells
Portfolio Manager (provided by EPA) – An interactive energy management software application made available to the public by the EPA and DOE that tracks and assess energy and water consumption across an entire portfolio of buildings and provides a ranking of a building's energy efficiency compared to other buildings of a similar size and use taking into account regional and seasonal variations in the weather.
Renewable energy – energy produced from sources that can be used indefinitely or over very long periods of time without exhausting the supply if property managed such as solar energy, flowing water, geothermal heat, bio-fuels or wood.
Renewable Energy Credits (REC's) – marketable environmental commodities in the U.S. which represent proof of electricity was generated from eligible renewable energy resources
Seasonal Energy Efficiency Rating (SEER)/Energy Efficiency Rating (EER) – measures of the efficiency of air-conditioning systems; ratio of the annual BTU's of cooling provided divided by the electric energy input used and measured over a range of temperatures
Smart Client – is a term used to describe electronic data management through a 'virtual desktop infrastructure' that reduces electricity consumption by eliminating the need for the more traditional desktop computer hardware of local hard drives, external hardware ports and floppy drives.
Solar Cells – cells that convert sunlight directly into electricity and are made of semiconductors such as crystalline silicon or various thin-film materials **Solar Energy** – heat and light energy produced by the sun

Solar Reflectance – measure of the ability of a surface material to reflect sunlight – including the visible, infrared, and ultraviolet wavelengths – scale of measure from 0 to 1. Also called albedo

Solid Waste Association of North America (SWANA) – leading professional association in the solid waste management field

Standard Planning Grade Energy Assessment– building assessments designed to identify and document energy-saving retrofit and upgrade opportunities

Sustainability – a lifestyle or the result of choices that meets the needs of the present without compromising the ability of future generations to meet their own needs; understand the interconnections of the economy, society and environment and supports equitable distribution of resources and opportunities

Thermal Energy – energy derived from heat

Therms – a unit of measure equal to 100,000 Btu's

Thermoplastic olefin (TPO) – blend of polymers with high reflective qualities used as a roofing material

Tier 1 Renewable sources – geothermal, hydro facilities under 30 MW, methane, ocean, qualifying biomass, solar, wind, and fuel cells

Tier 2 Renewable sources – municipal waste-to-energy projects, poultry litter, and existing hydro facilities over 30 MW