UNIT-V Part-I

Unit 5: Non-Conventional Power Plants

Solar Power Plant based on: flat plate collector, solar ponds, parabolic solar collector, heliostat, solar chimney, SPV cell based plants: working principal, solar photovoltaic systems, applications Geothermal Plant: superheated steam system, flash type, binary cycle plant.

Tidal Power Plant: components, single basin, double basin systems.

OTEC Plant: principal of working, Claude cycle, Anderson Cycle.

MHD Power Generation : Principal of working, Open Cycle MHD generator, closed cycle MHD generators.

Fuel cell : alkaline, acidic, proton-exchange membrane

Wind Power Plant : wind availability, wind mills and subsystems, classification of wind turbines, operating characteristics, wind solar hybrid power plants, challenges in commercialization of non-conventional power plants, environmental impacts of NCPP
Solar Energy/ Solar Electricity

• Solar Energy
• Do you know how big sun is? It is around triple three thousands (3,33,000) times bigger than earth. And It is around Ninety-three million miles away from us. The surface and core temperature of the sun as calculated are approx. 5,600°C and 1,50,00,000°C respectively. Nuclear reactions are continuously going on in the sun.
• It is a huge mass of constant nuclear activity. Only sun is the source of all kind of energy available on this planet.

• It provides the energy needed to survive all life forms in this planet. Sun controls the climates and weathers on this planet.

• It is obvious that the electrical energy we use in our daily life also indirectly comes from sun. Actually all kind of energy generation utilizes sun as ultimate source. So sunlight alone could also be a direct source of electricity.
• The surface of the earth receives $10^{14}$ kW of energy by sun.
• Sun will last for $10^{11}$ years.
• 1 m$^2$ of land receives 1 H.P or 1 kW when exposed directly to sun light.
• However this is not easily convertible & not free.
• **Obstacles:**
  1. It is not available constantly, thus storage is needed.
  2. It is diffused, thus needs large area for exploitation thus uneconomical.

**Advantages:**
1. It does not contaminate environment or endanger the ecological balance.
2. It avoids major problems like exploration, extraction and transportation.
Components of a Solar Electric Generating System

- **Solar Panels**
- The main part of a solar electric system is the solar panel. There are various types of solar panel available in the market. Solar panels are also known as photovoltaic solar panels.
- Solar panel or solar module is basically an array of series and parallel connected solar cells. The potential difference developed across a solar cell is about 0.5 volt and hence desired number of such cells to be connected in series to achieve 14 to 18 volts to charge a standard battery of 12 volts.
- Solar panels are connected together to create a solar array. Multiple panels are connected together both in parallel and series to achieve higher current and higher voltage respectively.
• **Batteries**

• In grid-tie solar generation system, the solar modules are directly connected to inverter and not with load. The power collected from solar panel not in constant rate rather it varies with intensity of sunlight. This is the reason why solar modules or panels do not feed any electrical equipment directly instead they feed an inverter whose output is synchronized with external grid supply.

• Inverter takes care of the voltage level and frequency of the output power from the solar system it always maintains with that of grid power level.

• As we get power from both solar panels and external grid power supply system, the voltage level and quality of power remain constant. As the stand-alone or grid fallback system is not connected with grid any variation of power level in the system can directly affects the performance of the electrical equipment fed from it. So there must be some means to maintain the voltage level and power supply rate of the system. **That is Battery bank**
• A battery bank connected parallel to this system takes care of that. Here the battery is charged by solar electricity and this battery then feeds a load directly or through an inverter.

• In this way variation of power quality due to variation of sunlight intensity can be avoided in solar power system (an uninterrupted uniform power supply is maintained). Normally Deep cycle lead acid batteries are used for this purpose.

• These batteries are typically designed to make capable of several charging and discharging during service. The battery sets available in the market are generally of either 6 volt or 12 volts. Hence number of such batteries can be connected in both series as well as parallel to get higher voltage and current rating of the battery system.
• **Controller**

• It is not desirable to overcharge and under discharge a **lead acid battery**. Both overcharging and under discharging can badly damage the battery system. To avoid these both situations a **controller** is required to attach with the system to maintain flow of current to and fro the batteries.
• **Inverter**

• It is obvious that the electricity produced in a solar panel is DC. Electricity we get from the grid supply is AC. So for running common equipment from grid as well as solar system, it is required to install an inverter to convert DC of solar system to AC of same level as grid supply.

• In off grid system the inverter is directly connected across the battery terminals so that DC coming from the batteries is first converted to AC then fed to the equipment.

• In grid tie system the solar panel is directly connected to inverter and this inverter then feeds the grid with same voltage and frequency power.
Types of Collectors

1. Flat plate: Long temp (=100°C) For
   a. water heating
   b. Space heating
   c. Space cooling
   d. Drying

2. Cylindrical Parabola: medium temp (100-200°C) For
   a. Vapour engines & turbines
   b. Process heating
   c. Refrigeration
   d. Cooking

3. Parabolloid mirror arrays: (> 200°C) For
   a. Steam engines & turbines
   b. Stirling engine
   c. Thermo electric generator
• Flat Plate collectors:

It consist of four essential components

a. **An absorber plate:** It intercepts & absorbs solar radiation. It is made up of Cu, Al or Steel. Sometimes it is coated with a material to enhance the absorption of solar radiation.

b. **Transparent covers:** These are one or more sheets of solar radiation transmitting materials and are placed above the absorber plate.

c. **Insulation beneath the absorber plate:** It minimizes and protects the absorbing surface from heat losses.

d. **Box:** It contains above elements & keeps them in position.

This type of collector is effective, reliable and inexpensive.
Flat Collector
Focusing or Concentrating collectors

- The main types of Focusing or Concentrating collectors are:
  1. Parabolic trough collector
  2. Mirror strip collector
  3. Fresnel less collector
  4. Flat plate collector with adjustable mirrors
  5. Compound parabolic concentrator.
Parabolic Collectors
Cylindrical parabolic Collector

Fig. 10.11. (b) Cylindrical parabolic system.
Solar Pond

• It is an effective collector of diffuse, as well direct radiation and will gather useful heat even on cloudy days.

• Under ideal conditions, the pond’s absorption efficiency can reach 50% of incoming solar radiation.

• Once the lower layer of the pond reaches over 60°C the heat generated can be drawn off through a H.E. & used to drive low temp organic Rankine cycle turbine.
Solar Pond

- The salt gradient solar pond normally consist of following three zones.

1. **Upper convective zone (UCZ):** It is a homogeneous convective zone that serves as a buffer zone between environmental fluctuations at the surface & conductive heat transport from the layer below.

2. **Lower convective zone (LCZ):** This is the layer with highest salt concentration and where high temp are built up.

3. **Intermediate gradient zone:** This zone keeps two convective zone separate and gives the solar pond its unique thermal performance. This zone provides excellent insulation for the storage layer, while transmitting solar radiation.

   To replace the amount of salt that is transported; salt must be added to LCZ and fresh water to UCZ, whilst brine is removed.

   The brine can be recycled as salt and water by solar distillation & returned to pond.

   To prevent major heat loss from surface of the solar pond, plastic grid is spread over the surface to minimize disturbance by wind.
Solar Pond

Fig. 10.12. Principle of solar pond.
A plastic liner or impermeable soil must be used to prevent infiltration into the nearby ground water or soil due to high salt concentration of LCZ. Liner is a factor that increases the cost of solar pond. The optical transmission properties & related collection efficiency vary greatly and depend on:

a. Salt concentration
b. The type of salt
c. The quantity of suspended dust or other particles.
d. Surface impurities like leaves or debris, biological material like bacteria and algae.

The higher efficiency and storage can be achieved through the utilization of refined or pure salt whenever possible, as this maximizes optical transmission.
Solar Pond Electric Power Plant

Fig. 10.13. Solar pond electric power plant. This diagram shows a solar pond with hot and cold brine systems, connected to a condenser, evaporator/boiler, turbine, and generator, generating electrical output.
Low temperature solar power plant
Low temperature solar power plant

- In this system an array of flat plate collectors is used to heat water to about 70°C and then this heat is used to boil butane in a heat exchanger.
- The high pressure butane vapour thus obtained runs a butane turbine which in turn operates a hydraulic pump.
- The pump pumps the water from the well which is used for irrigation purpose.
- The exhaust butane vapour (from butane turbine) is condensed with the help of water which is pumped by the pump & condensate is returned to the heat exchanger (or boiler).
High temperature solar power plant

Solar Farm and Solar Tower Plant

• For large scale production of process-heat the following two concepts are used:

1. The solar farm: It consists of a whole field covered with parabolic trough concentrators. Here temp at the point of focus can reach several hundred degrees Celsius.

2. The solar tower: It consists of central receiver on a tower and a whole field is of tracking. Here temp can reach thousands of degrees Celsius since a field of reflectors (heliostats) are arranged separately on sun tracking frames to reflect the sun energy on to a boiler mounted on central tower. (fig 10.17 & 10.18)
Solar Tower Power Plant
Solar Tower System
• With both the systems a heat transfer fluid or gas is passed through the point or line of insolation concentration to collect the heat and transfer it to the point of use.

• Such heat can be used either directly in industrial or commercial processes or indirectly in electricity production via steam and a turbine.

• The above technologies that produce the hot water or steam are currently under development and in general are not cost competitive with conventional ones.
In modern grid tie system, each solar module is connected to grid through individual micro-inverter to achieve high voltage alternating current from each individual solar panel.
• **Solar Electricity**

• When sunlight strikes on photovoltaic solar panels solar electricity is produced. That is why this is also referred to as photovoltaic solar, or PV solar.
Principles of Solar Electricity

• Generation of electricity by using **solar energy** depends upon the **photovoltaic effect** in some specific materials. There are certain materials that produce **electric current** when these are exposed to direct sun light. This effect is seen in combination of two thin layers of **semiconductor** materials.

• One layer of this combination will have a depleted number of electrons. When sunlight strikes on this layer it absorbs the photons of sunlight ray and consequently the electrons are excited and jump to the other layer.
• This phenomenon creates a charge difference between the layers and resulting to a tiny potential difference between them. The unit of such combination of two layers of semiconductor materials for producing electric potential difference with sunlight is called solar cell.

• Silicon is normally used as the semiconductor material for producing such solar cell. For building cell silicon material is cut into very thin wafers. Some of these wafers are doped with impurities. Then the un-doped and doped wafers are then sandwiched together to build solar cell. Metallic strip is then attached to two extreme layers to collect current.
• Conductive metal strips attached to the cells take the electrical current. One solar cell or photovoltaic cell is not capable of producing desired electricity instead it produces very tiny amount of electricity hence for extracting desired level of electricity desired number of such cells are connected together in both parallel and series to form a solar module or photovoltaic module.

• Actually only sunlight is not a factor; the main factor is light or beam of photons to produce electricity in solar cell. Hence a solar cell can also work in cloudy weather as well as in moon light but then electricity production rate becomes low as it depends upon intensity of incident light ray.
Application of Solar Electricity

• Solar electricity generation system is useful for producing moderate amount of power. The system works as long as there is a good intensity of natural sunlight.
• The place where solar modules are installed should be free from obstacles such as trees and buildings otherwise there will be shade on the solar panel which affects the performance of the system.
• It is a general view that solar electricity is an impractical alternative of conventional source of electricity and should be used when there is no traditional alternative of conventional source of electricity available.
• Often it is seems that solar electricity is more money saving alternative than other traditional alternatives of conventional electricity.
Diagram showing various applications of solar energy:

- Telecommunication
- Offshore Oil Drilling
- PV Refrigerator
- Power Pack (Army Tent)
- Solar Lantern
- Domestic Lighting System
- Battery Charging Station
- PV Integrated Building
- PV Pump
- Railway Signaling
History of Solar Energy

• First solar collector created by Swiss scientist named Horace-Benedict de Saussure in 1767 he take an insulated box enclosed with three layers of glass which suck up heat energy. After that Saussure’s box became famous and widely known as the first solar oven, getting temperatures of 230 degrees Fahrenheit.

• After that in 1839 a most important landmark in the progression of solar energy occurs with the significant of the photovoltaic effect by a French scientist Edmond Becquerel. In this he used two electrodes placed in an electrolyte and then exposing it to the light and results in electricity increased a lot. After that lots of experiment are carried by various scientists time to time and modified solar energy system to produce more electricity from solar energy.

• But still research is going on now a day’s to utilize maximum solar energy which is available on the earth.
• In 1873, Willoughby Smith discovered photoconductivity of a material known as selenium.
• In 1887 there was the discovery of the ultraviolet ray capacity to cause a spark jump between two electrodes and this was done by Heinrich Hertz.
• In 1891 the first solar heater was created. In 1893 the first solar cell was introduced. In 1908 William J. Baileys invented a copper collector which was constructed using copper coils and boxes.
• In 1958, solar energy was used in space. In the 1970’s, Exxon Corporation designed an efficient solar panel which was less costly to manufacture. Then onwards less cost manufacturing process of solar panel became the major milestone in the history of solar energy.
• In 1977 the US government embraced the use of solar energy by launching the Solar Energy Research Institute.
• In 1981, Paul Macready produced the first solar powered aircraft.
• In 1982 there was the development of the first solar powered cars in Australia.
• In 1999 the largest plant was developed producing more than 20 kilowatts.
• In 1999, the most proficient solar cell was developed with a photo-voltaic efficiency of 36%, now a day we produce 200 megawatts to 600 megawatts electricity from solar energy like in India’s Gujarat Solar Park, a compilation of solar farms spotted around the Gujarat region, show a mutual installed capacity of 605 megawatts and Golmud Solar Park in China, with an installed capacity of 200 megawatts.
• Criteria for Materials to be Used in Solar Cell
  • Must have band gap from 1ev to 1.8ev.
  • It must have high optical absorption.
  • It must have high electrical conductivity.
  • The raw material must be available in abundance and the cost of the material must be low.

• Advantages of Solar Cell
  • No pollution associated with it.
  • It must last for a long time.
  • No maintenance cost.

• Disadvantages of Solar Cell
  • It has high cost of installation.
  • It has low efficiency.
  • During cloudy day, the energy cannot be produced and also at night we will not get solar energy
• **Uses of Solar Generation Systems**
• It may be used to charge batteries.
• Used in light meters.
• It is used to power calculators and wrist watches.
• It can be used in spacecraft to provide electrical energy.
Different Parameters of solar cell

- **Short Circuit Current of Solar Cell**
- The maximum current that a solar cell can deliver without harming its own construction. It is measured by short circuiting the terminals of the cell at most optimized condition of the cell for producing maximum output. The term optimized condition is used because for fixed exposed cell surface the rate of production of current in a solar cell also depends upon the intensity of light and the angle at which the light falls on the cell. As the current production also depends upon the surface area of the cell exposed to light, it is better to express maximum current density instead maximum current. Maximum current density or short circuit current density rating is nothing but ration of maximum or short circuit current to exposed surface area of the cell.

\[ J_{sc} = \frac{I_{sc}}{A} \]

Where, \( I_{sc} \) is short circuit current, \( J_{sc} \) maximum current density and \( A \) is the area of solar cell.
• **Open Circuit Voltage of Solar Cell**
  It is measured by measuring *voltage* across the terminals of the cell when no load is connected to the cell. This voltage depends upon the techniques of manufacturing and temperature but not fairly on the intensity of light and area of exposed surface. Normally open circuit voltage of solar cell nearly equal to 0.5 to 0.6 volt. It is normally denoted by \( V_{oc} \).

• **Maximum Power Point of Solar Cell**
  The maximum *electrical power* one solar cell can deliver at its standard test condition. If we draw the v-i characteristics of a solar cell maximum power will occur at the bend point of the characteristic curve. It is shown in the v-i characteristics of solar cell by \( P_m \).
• **Current at Maximum Power Point**
  - The current at which maximum power occurs. Current at Maximum Power Point is shown in the v-i characteristics of solar cell by \( I_m \).

• **Voltage at Maximum Power Point**
  - The voltage at which maximum power occurs. Voltage at Maximum Power Point is shown in the v-i characteristics of solar cell by \( V_m \).

• **Fill Factor of Solar Cell**
  - The ratio between product of current and voltage at maximum power point to the product of short circuit current and open circuit voltage of the solar cell.

\[
Fill\ Factor = \frac{P_m}{I_{sc} \times V_{oc}}
\]
• **Efficiency of Solar Cell**

• It is defined as the ratio of maximum electrical power output to the radiation power input to the cell and it is expressed in percentage. It is considered that the radiation power on the earth is about 1000 watt/square metre hence if the exposed surface area of the cell is A then total radiation power on the cell will be 1000 A watts. Hence the efficiency of a solar cell may be expressed as

\[
\text{Efficiency}(\eta) = \frac{P_m}{P_{in}} \approx \frac{P_m}{1000A}
\]
Tidal power/OTEC

- **Tidal power**, also called tidal energy, is a form of hydropower that converts the energy obtained from tides into useful forms of power, mainly electricity.

- India is surrounded by sea on three sides, its potential to harness tidal energy is significant. Energy can be extracted from tides in several ways.

- In one method, a reservoir is created behind a barrage and then tidal waters pass through turbines in the barrage to generate electricity. This method requires mean tidal differences greater than 4 meters and also favourable topographical conditions to keep installation costs low.

- Most attractive locations in India, for the barrage technology, are the **Gulf of Khambhat** and the **Gulf of Kutch** on India's west coast where the maximum tidal range is 11 m and 8 m with average tidal range of 6.77 m and 5.23 m respectively.
• The Gange’s Delta in the Sunderbans West Bengal is another possibility. The maximum tidal range in Sunderbans is approximately 5 m with an average tidal range of 2.97 m.

• Acc to report, barrage technology could harvest about 8 GW from tidal energy in India, mostly in Gujarat.

• The barrage approach has several disadvantages, one being the effect of any badly engineered barrage on the migratory fishes, marine ecosystem and aquatic life.
• Another tidal wave technology harvests energy from surface waves or from pressure fluctuations below the sea surface.

• India built its first seas surface energy harvesting technology demonstration plant in Vizhinjam, near Thiruvanananthpuram.

• A report from the Ocean Engineering Centre, Indian Institute of Technology, Madras estimates the annual wave energy potential along the Indian coast is between 5 MW to 15 MW per metre, and maximum potential for electricity harvesting from India's 7500 kilometre coast line may be about 40 GW.
Tidal Power Plants

• The periodic rise & fall of the water level of sea which is carried by the action of sun and moon on water of the earth is called “tide”.

• The main feature of tidal cycle is the difference in water surface elevations at the high tide and at the low tide.

Components:
1. The dam or dyke (low fall) to form pool or basin.
2. Sluice ways from the basins to the sea and vice- versa.
3. The power house.

Classification:
1. Single basin arrangement
2. Double basin arrangement
Advantages

1. It is completely independent of rain & its uncertainty.
2. Large area of land is not required.
3. When this is operated with thermal or hydro-electric system peak power demand can be effectively met.
4. It is free from pollution.
Disadvantages

1. Due to variation in tidal range the o/p is not uniform.
2. Plant efficiency affected as turbine has to work with wide range of head variation.
3. Fear of corrosion of machinery due to sea water.
4. It is difficult to carry out construction in sea.
5. Some what costly.
6. Sedimentation & silteration of basins are the problems.
7. Power transmission cost is high as these are located away from load centres.

The first commercial tidal power station was constructed in France in 1965 across the mouth of La Rance Estuary. It has capacity of 240 MW. The average tidal range is 8.4m, and encloses an area of 22 km².
The third approach of harvesting tidal energy consists of ocean thermal energy technology. This approach tries to harvest the solar energy trapped in ocean waters into usable energy.

Oceans have a thermal gradient, the surface being much warmer than deeper levels of ocean. This thermal gradient may be harvested using modified **Rankine cycle**.
• In 2003, with Saga University of Japan, NIOT attempted to build and deploy a 1 MW demonstration plant over the last 20 years.
• However, mechanical problems prevented success. After initial tests near Kerala, the unit was scheduled for redeployment and further development in the Lakshadweep Islands in 2005.
• The demonstration project's experience have limited follow-on efforts with ocean thermal energy technology in India.
Geothermal energy-India scenario

- According to some estimates, India has 10,600 MW of potential in the geothermal provinces but it still needs to be exploited. India has potential resources to harvest geothermal energy. The resource map for India has been grouped into six geothermal provinces:
  - **Himalayan Province** – Tertiary Orogenic belt with Tertiary magmatism
  - Areas of Faulted blocks – Aravalli belt, Naga-Lushi, West coast regions and Son-Narmada lineament.
  - Volcanic arc – Andaman and Nicobar arc.
  - Deep sedimentary basin of Tertiary age such as Cambay basin in Gujarat.
  - Radioactive Province – Surajkund, Hazaribagh, Jharkhand.
  - Cratonic province – Peninsular India.
Fig. 10.19. Hot spring system structure.
Fig. 10.20. Dry-steam open system.
Fig. 10.21. Flash steam open type system.
Fig. 10.22. Hot water closed (Binary) system.
India has about 340 hot springs spread over the country. Of this, 62 are distributed along the northwest Himalaya, in the States of Jammu and Kashmir, Himachal Pradesh and Uttarakhand. They are found concentrated along a 30-50-km wide thermal band mostly along the river valleys.

Naga-Lusai and West Coast Provinces manifest a series of thermal springs. Andaman and Nicobar arc is the only place in India where volcanic activity, a continuation of the Indonesian geothermal fields, and can be good potential sites for geothermal energy.

Cambay graben geothermal belt is 200 km long and 50 km wide with Tertiary sediments. Thermal springs have been reported from the belt although they are not of very high temperature and discharge. During oil and gas drilling in this area, in recent times, high subsurface temperature and thermal fluid have been reported in deep drill wells in depth ranges of 1.7 to 1.9 km. Steam blowout have also been reported in the drill holes in depth range of 1.5 to 3.4 km.
• In a December 2011 report, India identified six most promising geothermal sites for the development of geothermal energy. These are, in decreasing order of potential:
  • Tattapani in Chhattisgarh
  • Puga in Jammu & Kashmir
  • Cambay Graben in Gujarat
  • Manikaran in Himachal Pradesh
  • Surajkund in Jharkhand
  • Chhumathang in Jammu & Kashmir

• India plans to set up its first geothermal power plant, with 2–5 MW capacity at Puga in Jammu and Kashmir
Magneto hydrodynamics system (MHD)

- Direct energy conversion devices are those who convert natural available energy into electricity without an intermediate conversion into mechanical energy.
- MHD is one of them & is concerned with the flow of conducting fluid in the presence of magnetic and electric field. The fluid may be gas at elevated temp or liquid like sodium or potassium.
- MHD generator is a device which converts heat energy of a fuel directly into electricity without an conventional electric generator.
- MHD is like a heat engine whose efficiency can be increased by supplying heat at highest practical temp & rejecting at lowest practical temp.
- MHD is most promising one among direct energy conversion devices for large scale production of electric power.
Principle of MHD Power Generation

• MHD uses Faraday’s law of electromagnetic induction which states that when a conductor and magnetic field move in respect to each other, an electric voltage is induced in the conductor.

• The conductor need not be a solid- it may be liquid or gas. So MHD forces a high pressure and high temp combustion gas through a strong magnetic field.
• Classification of MHD

1. Open cycle systems- Seeded inert gas systems

Here fuel is oil, Coal or NG and air. Hot gases produced are seeded with small amount of ionized alkali metal (Cesium or Potassium) to increase the electrical conductivity of gas. Ionization of potassium carbonate takes place due to the gases produced at temp of about 2300-2700°C by combustion.

Hot pressurized working fluid so produced leaves the combustion chamber & passes through a convergent-divergent nozzle which increases its velocity then enter MHD generator. The expansion of the hot gases takes place in the generator surrounded by powerful magnets. Then it produces DC current & by using inverter it is converted to AC current.
Fig. 10.30. Open cycle MHD system.
2. Closed cycle systems (Liquid metal systems-potassium)

Here the liquid potassium after being heated in the breeder reactor is passed through the nozzle to increase its velocity.
The vapour formed due to nozzle action is separated in separator & condensed & pumped back to reactor.
The liquid metal with high velocity is passed through MHD generator to produce D.C and then A.C. by using inverter.
The liquid potassium coming out of MHD is passed through heat exchanger (boiler) to use its remaining heat to run a turbine and then pumped back to the reactor.

This system entails many constructional and operational difficulties.
Advantages of MHD systems

• More reliable since no moving parts.
• Efficiency can be 50%
• Free of pollution
• It can reach full power level as soon as it starts.
• Size of plant is small.
• Less overall operational cost
• Capital cost is comparable.
• Better utilization of fuel.
• Suitable for peak power generation & emergency service.
Drawbacks of MHD

• It suffers from reverse flow (short circuits) of electrons through the conducting fluids around the ends of magnetic field.
• There will be high friction & heat transfer loss.
• It needs very large magnets and is expensive.
• Coal can’t be used as its molten ash may short circuit the electrodes. Hence oil or NG is used as fuel which is expensive for operation.
• It operates at high temp, but electrodes must be relatively at lower temp, hence gases near electrodes are cooler. This increases the resistivity of the gas near the electrodes and hence there will be very large voltage drop across the gas film. By adding seed material the resistivity can be reduced.
Fuel Cell

• A fuel cell is an electrochemical device in which the chemical energy of a conventional fuel is converted directly and efficiently into low voltage, DC electrical energy.

• It is often described as primary battery in which the fuel & oxidizer are stored external to the battery and fed to it as needed.

Following fig shows the schematic diagram of fuel cell. The fuel gas diffuses through the anode and is oxidized, thus releasing electrons to the external circuit: the oxidizer diffuses through the cathode and is reduced by the electrons that have come from the anode by way of external circuit.

Of the available, hydrogen fuel cell is popular, though coal, oil or NG much useful.
Fig. 10.34. Schematic of a fuel cell.

Some of the possible reactions are:

- Hydrogen/oxygen: 1.23 V
  \[ 2H_2 + O_2 \rightarrow 2H_2O \]

- Hydrazine: 1.56 V
  \[ N_2H_4 + O_2 \rightarrow 2H_2O + N_2 \]

- Carbon (coal): 1.02 V
  \[ C + O_2 \rightarrow CO_2 \]

- Methane: 1.05 V
  \[ CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O \]
Hydrogen-oxygen fuel cell

- It is typical of fuel cell.
- It has three chambers separated by two porous electrodes, the anode & cathode.
- The middle chamber between the electrodes is filled with strong solution of potassium hydroxide.
- The surface of the electrodes are chemically treated to repel the electrolyte, so that there is a min leakage of potassium hydroxide into the outer chambers.
- The gases diffuse through the electrodes undergoing reactions like:
  \[ 4\text{KOH} \rightarrow 4\text{K}^+ + 4(\text{OH})^- \]
  Anode: \[ 2\text{H}_2 + 4(\text{OH})^- \rightarrow 4\text{H}_2\text{O} + 4\text{e}^- \]
  Cathode: \[ \text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \rightarrow 4(\text{OH})^- \]
- Cell reaction \[ 2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O} \]
• The water formed is drawn off from the side.
• The electrolyte provides the (OH)⁻ ions needed for the reaction, and remains unhanged at the end, since these ions are regenerated.
• The electrons liberated at the anode find their way to the cathode through the external circuit.
• This transfer is equivalent to the flow of a current from the cathode to the anode.
• Such cells when properly designed & operated, have an open circuit voltage of about 1.1 volt.
• But there life is limited since the water formed continuously dilutes the electrolyte.
• Fuel efficiencies as high as 60-70% may be obtained.
Fig. 10.35. Hydrogen-oxygen fuel cell.
Advantages of fuel cells

1. Conversion efficiencies are high.
2. Require little attention & less maintenance.
3. Can be installed near the use point, thus reducing transmission requirements and accompanying losses.
4. Fuel cell does not make any noise.
5. A little time is needed to go into the operation.
6. Space requirements considerably less in comparison to conventional power plants.
Disadvantages of fuel cell

1. High initial cost.
2. Low service life.

Applications of fuel cells:
1. Domestic use
2. Automotive vehicles
3. Central power stations
4. Special applications.
Hybrid Power Plants

• Combination of two power plants.
Challenges in commercialization of Non-Conventional Power Plants.
THANK YOU