DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

Subject Name: Renewable Energy Sources

Subject Code: EE E12

UNIT I

GENERAL

Conventional and non-conventional sources of energy-Energy reserves in India. Limitations of Conventional sources of energy-Energy Efficiency-Energy Conservation-Dispersed Generation.

2- MARKS

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. **Define primary energy sources.** **(Nov 2011) (April 2015)**

   Primary energy is an energy form found in nature. This is the energy found in raw form is called raw energy .It cannot be used as such.

   Eg: Coal, oil, sunlight, wind, running rivers, uranium, etc.

3. **What are the available energy sources for various power plants?**

   i. Conventional energy sources or Non-renewable energy sources

   ii. Non-conventional energy sources or Renewable energy sources

4. **What are the major power limitations of conventional energy sources?**

   i. Resources for power generation i.e, coal, gas etc., are limited.

   ii. The hydro power is seasonal and varies depending upon the rainfall in the catchment areas.

iii. Submersion of land area due to raise in water level.
iv. Centralized power generation and distribution of the same to long distances will result in high losses.
v. The energy conversion process from thermal power projects results in emission of greenhouse gases.

5. **List out the various conventional and non-conventional power plant.**

(April/May 2012) (April/May 2014)

Types of conventional power plant:

1. Hydro power plant
2. Steam power plant
3. Nuclear power plant
4. Gas turbine power plant

Types of non-conventional power plant:

1. Tidal power plant
2. Wind power plant
3. Geothermal power plant
4. Solar power plant
5. Wave power plant

6. **What is conventional energy Sources?**

The conventional sources of energy are generally non-renewable sources of energy, which are being used since a long time. These sources of energy are being used extensively in such a way that their known reserves have been depleted to a great extent.

Eg: Nuclear, hydro and fossil fuel

7. **What is nonconventional energy Sources?**

Non-conventional energy sources are the energy sources which gives renewable energy. The energy which never gets depleted is called non-conventional energy . Non-conventional sources of energy are those which are abundantly available in nature,

Eg: Solar, wind, biomass, etc.

8. **What is mean by Intermediate resources?**

It is obtained from primary energy by one or more steps of transformation.

Eg: energy used in vehicle

9. **What are the Secondary energy Sources?** **(April/May 2014)**

The form of energy which is finally supplied to a consumer for utilization is known as secondary or usable energy, e.g, electrical energy, thermal energy (in the form of steam or hot water), chemical energy (in the form of hydrogen or fossil fuels), etc. some form of energy may be categorized both in intermediate as well as secondary resources, e.g., electricity and hydrogen

10. What are the advantages of renewable energy? **(April/May 2014)**

- No Global Warming Emissions
- Improved Public Health and Environmental Quality
- A Vast and Inexhaustible Energy Supply
- Jobs and Other Economic Benefits
- Stable Energy Prices
- A More Reliable and Resilient Energy System

11. What is the difference between renewable and non-renewable energy resources?

(April 2012)

Sl.no	Renewable energy	Nonrenewable energy
1.	Renewable energy is energy which is generated from natural sources i.e. sun, wind, rain, tides and can be generated again and again as and when required.	Non-Renewable energy is energy which is taken from the sources that are available on the earth in limited quantity and will vanish fifty-sixty years from now.
2.	They are available in plenty and by far most the cleanest sources of energy available on this planet.	Non-renewable sources are not environmental friendly and can have serious effect on our health.
3.	wind, geothermal, biomass ,solar	Fossil fuels, natural gas, oil and coal.

12. Which region in India producing more wind power?

Sl.No	State	Wind Power
1.	Tamil Nadu	8,256 MW
2.	Maharashtra	4167.26 MW
3.	Gujarat	3,087 MW
4.	Rajasthan	2355 MW
5.	Madhya Pradesh	386 MW

13. State the world wide status of India in coal energy. **(April/May 2012)**

India is ranked 3rd in the world coal production. The production of coal was 532.63 million metric tons in the year 2010 – 11. The Indian coal has on an average of about 18 to 22% ash content. The coal availability in India will last for 50 to 60 years.

14. List out the availability of nuclear fuel in India. **(April 2013)**

In India it is available as inland resources in the Ranchi plateau. Apart from there they are available as scattered deposits in the Gujarat region, Bihar and inner Tamil Nadu.

15. Write the renewable energy sources utilized in India. **(Nov/Dec 2014)**

1. Solar power plant
2. Wind power plant
3. Hydro power plant
4. Geothermal power plant

16. Name any two types of nuclear fuels used as conventional energy sources. **(Nov 2011)**

U238, P234 and U235.

17. Define energy conservation? **(April 2015)(April/May 2014)**

It is defined as substitution of energy with capital, labour material and time. Energy conservation means reduction in energy consumption but without making any sacrifice of quantity and quality of production.

18. What are the principles of energy conservation? **(Nov 2013)(Nov/Dec 2014)**

The two principles of governing energy conservation policies are maximum thermodynamic efficiency and maximum cost effectiveness in energy use.

19. What are the steps to be followed for energy conservation? **(April 2013)**

The two principles of governing energy conservation policies are maximum thermodynamic efficiency and maximum cost effectiveness in energy use.

20. What are called as secondary fuels? **(Nov 2013)**

Secondary fuels are fuels that are derived from some primary fuel or fuels through chemical or physical processes. These are fuels that are not found as a natural resource.

21. List out the sources of Biogas. **(Nov 2013)**

Biogas typically refers to a mixture of different gases produced by the breakdown of organic matter in the absence of oxygen. Biogas can be produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste.

11 MARKS

1. **What are the prospective of renewable energy sources?**

(Nov 2012) (April/May 2014) (April 2013)

Life on the planet earth is the manifestation of energy. The origin of fire, heat and light is energy. It is required to grow food grains which enable humans and animals to survive and work. Energy causes the great universal movement on Earth on its axis and around the sun. The term 'energy' can be described as 'capacity to do work'. In early days, human beings used their own strength in carrying loads and collecting their food, and later started depending on natural energy sources like the power of falling water used for grinding corn and wind energy for sailing boats. In industry, initially the energy source was fire that used to be obtained by burning wood. Subsequently, wood become a source of charcoal that was used to extract metals from ores.

The fossil fuels were exploited as surface deposits of asphalt, peat and coal, oil from surface seepage and gas venting from underground reservoirs. The widespread use of petroleum began during 20th century, particularly for cars and buses, aero planes and industries. The use of energy got enhanced with the invention of electricity and development of electric energy generating stations consuming either fossil fuels or potential energy of water. The Second World War ended in 1945 with the invention and use of nuclear energy.

2. **Explain about the Common forms of energy.**

Kinetic energy:

The energy of an object in motion is called kinetic energy. If the mass of an object is moving with a velocity v, its kinetic energy in joules is expressed as K.E. = (1/2) mV^2, where m is in kg and V in m/s.

Potential energy:

The energy which a body possesses as a result of its position in earth's gravitational field is called potential energy and is expressed in joules as P.E.=mgh, where m is mass in kg, g is the acceleration due to gravity in $m/s^{2,}$ and h is the height in m.

Heat energy:

Heat is an intrinsic energy of all the combustible substances. It is the kinetic energy of molecules. Heat energy for example can cause gases to expand, drive engines and raise the temperature of water.

Chemical Energy:

Chemical energy is tied up in fossil fuels such as coal, oil and gas. Fossil fuels are used to generate electricity and power vehicles engines. Chemical energy in the food helps us to sustain our life.

Radiant Energy:

Solar radiation is the manifestation of radiant energy that is received on earth. Radio waves, X-rays, infra-red and ultra violet electromagnetic radiation contain radiant energy.

Electrical Energy:

Electrical energy arises out of the arrangement of movement of electrons to produce heat, magnetic field and electromagnetic radiations. It is highly versatile form of energy and can easily be converted to other forms of utilization.

Nuclear Energy:

Matter can be changed into energy when larger atoms are split into smaller ones (atomic fission) or when smaller ones combine to form larger atoms (atomic fusion).

3. **Explain about the various conventional energy sources and their availability?**

(April/May 2012)

Explain in detail about the availability of oil, hydro, natural gas and coal power.

(Nov 2012) (April 2015) (April 2013)

WORLD ENERGY SCENARIO

Present situation

The IEA estimated that in 2012 the world energy consumption was 146.37 GWhr. But **in year 2014 the world energy consumption increased to 150.35 GWhr . Around 80.6% of the total energy consumption of the world still comes from fossil fuels.**

Energy resources	**2013**		**2014**	
	GWhr	**%**	GWhr	**%**
coal	44.97	30.19	45.14	30.02
natural gas	35.50	23.83	35.65	23.71
oil	48.60	32.63	48.97	32.57
nuclear energy	6.55	04.40	6.67	04.43
hydro electricity	10.02	06.72	10.22	06.79
renewables	3.29	02.20	3.68	02.45
Total	148.94		150.35	

AVAILABILITY OF RESOURCES AND FUTURE TRENDS:

1. CONVENTIONAL RESOURCES

(i). Fossil fuel

Fossil fuels are so called because these are in fact the fossils of old biological life that once existed on the surface of the earth**. It is formed in several parts of the earth at varying depths, during several million years by slow decomposition and chemical actions of buried organic matter under favorable pressure, heat and bacterial marine environment. The fossil fuels include coal, oil and gas.**

Fossil fuels have been a major of energy since about 1850, the start of the industrial era. **Presently, we are passing through the peak of the fossil age.** It is generally accepted that the rate of production of an economic commodity of which a finite quantity exists is governed by the law of supply and demand. **As the amount available depletes, the commodity becomes costlier, and its use gradually declines.** Also, new reserves are continuously being discovered and new technologies are being invented for those resources which were not considered economical earlier.

Coal:

World total proved coal reserves are 891531 Million tonnes of oil equivalent (Mtoe) in 2014 were sufficient to meet 110 years of global production. The coal reserve is found to be abundant in European countries followed by Asia Pacific then North America etc. **The total coal production is 3933.5 Mtoe out of this the highest coal production is in Asia pacific which is about 2722.5 million tonnes of oil equivalent.**

Sl.No	**Name of the country**	**Total coal reserve Million tonnes of oil equivalent**	**Total coal production Million tonnes oil equivalent**	**Total coal consumption Million tonnes oil equivalent**
1.	North America	245,088	551.4	488.9
2.	S. & Cent. America	14,641	65.0	31.6
3.	Europe & Eurasia	310,538	441.6	476.5
4.	Middle East	32,936	0.7	9.7
5.	Africa	32,936	152.2	98.6
6.	Asia Pacific	288,328	2722.5	2776.6
7.	India	60600	243.5	50.6
8.	**Total World**	**891531**	**3933.5**	**3881.8**

Oil:

Total world proved oil reserves reached 1700.1 billion barrels at the end of 2014 sufficient to meet 52.5 years of global production. The largest reserve is from Middle East which is calculated as 810.7 billion barrels whereas the lowest oil reserve is 5.7 billion barrels which is from India. **The total oil production in India is 88673 thousand barrels daily and the total oil consumption is 92086 thousand barrels daily.**

Sl.No	Name of the country	Total oil reserve billion barrels	Total oil production Thousands barrels daily	Total oil consumption Thousands barrels daily
1.	North America	232.5	18721	23347
2.	S. & Cent. America	330.2	7613	7125
3.	Europe & Eurasia	154.8	17198	18252
4.	Middle East	810.7	28555	8706
5.	Africa	129.2	8263	3800
6.	Asia Pacific	42.7	8324	30856
7.	India	5.7	895	3846
8.	World	1700.1	88673	92086

Natural gas reserves:

World total proven natural gas reserves at end-2014 stood at 187.1 trillion cubic metres (tcm), sufficient to meet 54.1 years of global production. The Total proved reserves grew by 0.3% relative to end-2013. In global Middle East hold the largest proved reserves. The total natural gas production is about 3460.6(tcm) . World natural gas production increased by 1.6% in 2014 below its 10-year average of 2.5%, four times the growth rate of global consumption (+0.4%). **The total natural gas consumption is about 3393.0(tcm). The world largest natural gas consumption is 1009.6(tcm).**

Sl.No	Name of the country	Total natural gas reserve Trillion cubic meters	Total natural gas production Trillion cubic meters	Total natural gas consumption Trillion cubic meters
1.	North America	12.1	948.4	949.4
2.	S. & Cent. America	7.7	175.0	170.1
3.	Europe & Eurasia	58.0	1002.4	1009.6
4.	Middle East	79.8	601.0	465.2
5.	Africa	14.2	202.6	120.1
6.	Asia Pacific	15.3	531.2	678.6
7.	India	1.4	31.7	50.6
8.	World	187.1	3460.6	3393.0

(ii). Hydro Resources:

Among all renewables, hydro power is the most advanced and flexible source of power. It is a well-developed and established source of electric power. The early generation of electricity from about 1880, was often derived from hydro turbines. A number of large and medium sized hydro schemes have been developed. **Due to requirements of huge capital investment and strong environmental concerns about large plants, only about one third of the realistic potential has been tapped so far.**

Hydro installation and plants are long lasting. This is due to continuous steady operation without high temperature or other stresses. Therefore, it often produces electricity at low cost with consequent economic benefits.

At the end of 2011, over 160 countries had hydropower resources capacity, with a total capacity of 22464 GWh across 11,000 hydropower stations. **In 2014 the world total installed capacity is about 37686 TWh across all over world which accounts for about 16% of the world's total installed electric power generation capacity and about 2.3% of the world's primary energy supply.** Five countries make up more than the half of the world's hydro power production: in China 1,029.34 TWh, Canada 375.11 TWh Brazil 366TWh USA 259 TWh and Russia 169 TWh. **The world's biggest power plant is the Three Gorge Dam in China which at 540 GWh is more than 50% larger than the 2nd biggest power station in the world and with the Itaipu Dam in Brazil/Paraguay in second place (336 GWh).**

(iii). Nuclear resources

U^{235}, U^{233}(Isotopes of Uranium) and Pu^{239}(Plutonium) are used as nuclear reactors(thermal reactors) and are known as fissile(or fissionable) materials. Out of this, only U^{235} occurs in nature. U^{233} and Pu^{235} are produced from Th^{232}(Thorium) and U^{238} respectively in fast breeder reactors. Th^{232} and U^{238} are known as fertile materials. Natural Uranium contains of 0.71% of U^{235} and 99.29% of U^{238}.

Uranium reserves in the world are small and its recovery is expensive. Major top five available sources of uranium are in Australia(1706100 tonnes), Kazakhstan (679,300 tonnes), Russia(505,900 tonnes), Canda(493,900 tonnes) and in Niger(404,900 tonnes).

Nuclear power is a least cost, low emission technology that can provide base load. **As on 2015, there are around 439 nuclear power plants in the world, operating in 47 countries and generating 2417.2 TWh, which is about 19.5% of the world's electricity.** Top five countries generating nuclear power are USA(797 TWh), France(416 TWh), Russia (169 TWh), Korea(149 TWh) and China(131 TWh). **Tokyo Electric Power Co.'s (TEPCO) Kashiwazaki-Kariwa plant in Japan is currently the world's largest nuclear power plant, with a net capacity of 191.11 GWh.**

France produces 76.9% of its total power by nuclear means. Presently, most commercial reactors are thermal reactors. Fast breeder reactors utilize fast neutrons and generate more fertile material into fissile material than they consume. They generate energy as well as convert fertile material into fissile material.

Nuclear fusion reaction has a lot more potential and vast resources are available. However control fusion reaction has not been achieved yet.

It is predicted that by year 2500 some breakthrough will take place in fusion technology and once this happens nuclear, nuclear fusion reaction will be the main source of energy on the earth.

2. NON-CONVENTIONAL SOURCES

Non-conventional technologies are presently under the development stage. At present their share is very small.

(i). Solar energy

Solar energy can be a major source of power and can be utilized by using thermal and photo voltaic conversion systems. The solar radiations receive on the surface of the earth on a bright sunny day at noon is approximately 1 KW/m^2. The earth continuously intercepts solar power of 178 billion megawatt which is about 10000 times the world demand. But so far, could not be developed on a large scale. According to one estimate if all the buildings of the world are covered with solar PV panels it can fulfill electrical power requirements of the world**. Solar power is considered an expensive source of power.** At present, the capital cost of a solar PV system is Rs.200 per Watt(Rs.20 crore /MW as against Rs.4 crore /MW for coal fires thermal power plant.

By the end of 2014, cumulative photovoltaic capacity increased by more than 960 (GWh) and reached at least 4272 GWh, sufficient to supply 1 percent of the world's total electricity consumption . The top installers of 2014 were Germany (916.8 GWh), followed by China (674.4 GWh) and in Japan (559.2 GWh)

(ii). Wind energy:

Wind power has emerged as the most economical of all renewable energy sources. The installation cost of wind power is Rs. 4 crore/MW(which is comparable to that conventional thermal power plants). There has been remarkable growth of wind power installation in the world. Wind power generation is the fastest growing energy source.

The total electric power generation from wind is 6999 TWh at the end of 2014, USA leads the world in terms of installed wind capacity (182 TWh) followed by china (148 TWh) , Spain(80 TWh), Spain (80 TWh), Germany (58 TWh) and India (35 TWh) .

(iii). Biomass energy:

Energy resources available from animal and vegetation are called bio mass energy resources. This is an important resource for developing countries, especially in rural areas. The principle biomass resources are

- **Trees(wood, leaves and forest industry waste)**
- **Cultivated plants grown for energy**
- **Algae and other vegetation from oceans and lakes**
- **Urban waste(Municipal and industrial waste)**
- **Rural waste(agricultural and animal waste, crop residue etc)**

At present there are about 227 biogas plants all over the world with a total capacity of about4454 TWh. USA is the leading country which produces about 79 TWh power, followed by Brazil(57 TWh), Germany (44 TWh), China(44 TWh) and Japan 35(TWh)

(iv). Geothermal energy

Geothermal thermal energy is derived from huge amounts of stored thermal energy in the interior of the earth, though its economic recovery on the surface of the earth is not feasible everywhere. Its overall contribution in total energy requirement is negligible. **The total electric power generation from Geo thermal energy is 207o TWh. The countries like Island(79 TWh), Zimbabwe(17 TWh), Pierre (14 TWh) and India (10 TWh).**

(v). Ocean tidal energy

Tidal energy is a form of hydro power that converts energy of ocean tides into electricity are other useful forms of power. It is in the developing stage and although not yet widely used, tidal power has potential for future electricity generation. Tides are more predictable than wind energy and solar power. There are a number of large commercial scale tidal power sites in operation around the world. **The largest tidal power station in the world was commissioned in South Korea in 2011 and has a maximum generating capacity of 254 MW. It is known as the Sihwa Lake Tidal Power Station** and is an interesting construction because it retrofitted an existing seawall with ten 25.4 MW submerged turbines to produce electricity from the tidal flows. **The next largest is a 240 MW bulb turbine at the mouth of La Rance estuary in France.** That site powers a city of 300,000 people. Another of the older barrage tidal dams is the Annapolis Royal Generating Station which is located on the Annapolis River in Nova Scotia, Canada. With a generating capacity of 20 MW the power station was commissioned in 1984. It has the capability to power around 4500 houses in the area.

(vi). Ocean Wave energy

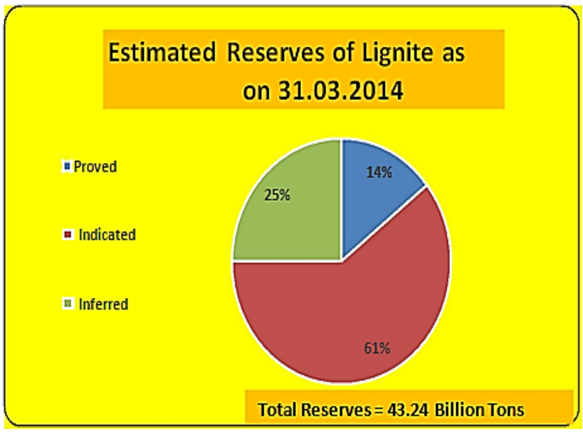
Wave power refers to the energy of ocean surface waves and the capture of that energy to do useful work. Good wave power locations have a flux of about 50 KW/m of shore line. The world's first grid-connected wave power station has been activated off the coast of Western Australia.

4. Explain in detail about resources for power generation in India. **(April/May 2014)**

(i) Coal and Lignite

- Coal deposits are mainly confined to eastern and south central parts of the country. The states of Jharkhand, Odisha, Chattisgarh, West Bengal, Madhya Pradesh, Andhra Pradesh and Maharashtra account for more than 99% of the total coal reserves in the country. The State of Jharkhand had the maximum share (26.81%) in the overall reserves of coal in the country as on 31st March 2014 followed by the State of Odisha(24.94%).
- As on 31.03.14 the estimated reserves of coal was 301.05 billion tons, an addition of 2.11 billion over the last year (Table 1.1). There has been an increase of 0.7% in the estimated coal reserves during the year 2013-14 with Odisha accounting for the maximum increase of 1.85%

- The estimated total reserves of lignite as on 31.03.14 was 43.24 billion tons against 43.22 billion tons as on 31.03.13.
- The availability of coal in the year 2013-14 increased by 4.11% compared to 2012-13. The availability of lignite decreased by 4.59% during the same period.



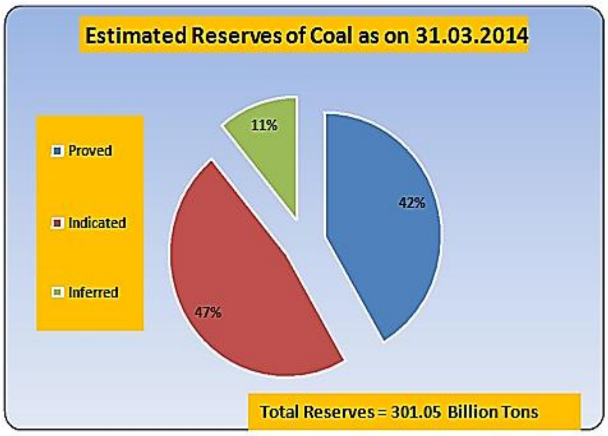


Table 1.1: Statewise estimated Reserves of Coal in India as on 31.03.2014

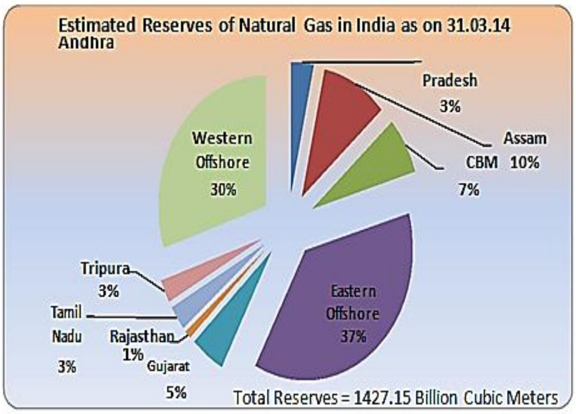
States/ UTs	**Total (in Billion Tons) 31.03. 14**
Andhra Pradesh	22.47
Arunachal Pradesh	0.09
Assam	0.00
Bihar	0.16
Chhattisgarh	52.53
Jharkhand	80.72
Madhya Pradesh	25.67
Maharashtra	10.96
Meghalaya	0.58
Nagaland	0.32
Odisha	75.07
Sikkim	0.10
Uttar Pradesh	1.06
West Bengal	31.32
All India Total	**301.05**

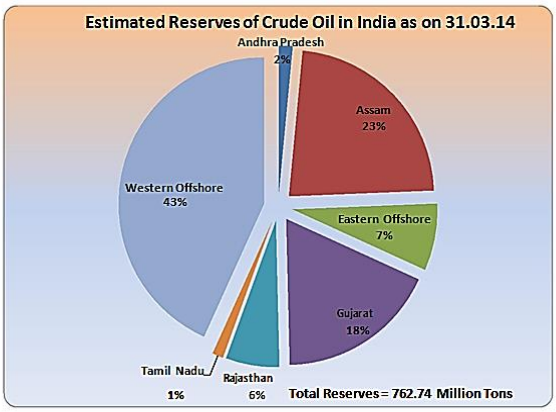
Table1.1(A): Statewise Estimated Reserves of Lignite in India as on 31.03.2014

States/ UTs	Total(in Billion Tons) 31.03. 14
Gujarat	2.72
Jammu & Kashmir	0.03
Kerala	0.01
Pondicherry	0.42
Rajasthan	5.72
TamilNadu	34.35
India	**43.24**

(ii) Petroleum and Natural gas

- The estimated reserves of crude oil in India as on 31.03.2014 stood at 762.74 million tons (MT).
- Geographical distribution of Crude oil indicates that the maximum reserves are in the Western Offshore (42.91%) followed by Assam (22.69%), whereas the maximum reserves of Natural Gas are in the Eastern Offshore (37.24%) followed by Western offshore (30.17%).

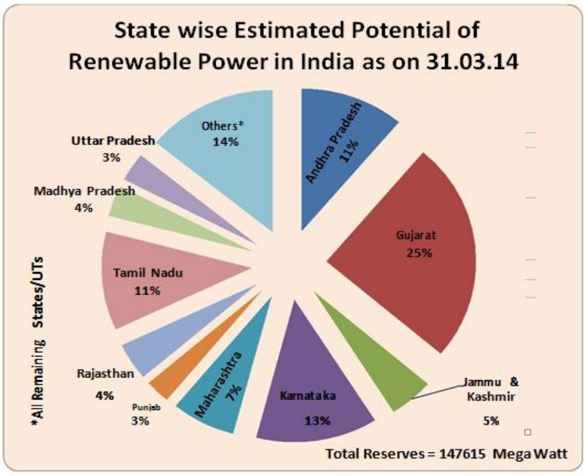


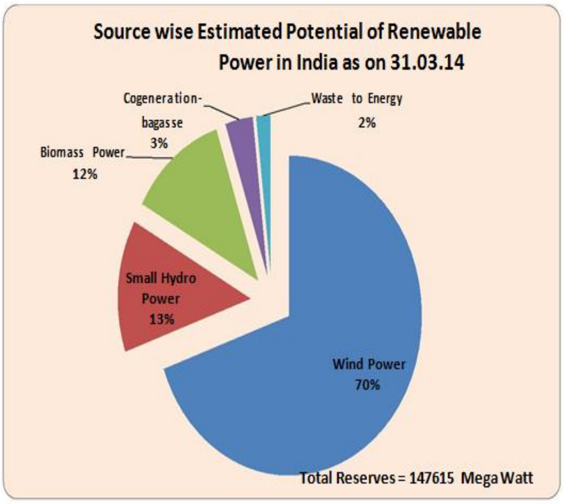


- In case of Natural Gas, the increase in the estimated reserves over the same period was 5.34%. The maximum contribution to this increase has been from Eastern Offshore (12.26%), followed by Western Offshore (3.6%).
- The production of natural gas has steadily increased from a mere 31.33 BCMs during 2005-06 to 34.64 BCMs during 2013-14, registering a CAGR of 1.12%. Most of this increase in the indigenous production is due to discovery of new reserves.

(iii) Renewable energy sources

- There is high potential for generation of renewable energy from various sources- wind, solar, biomass, small hydro and cogeneration bagasse.
- The total potential for renewable power generation in the country as on 31.03.14 is estimated at 147615 MW (Table 1.3). This includes wind power potential of 102772 MW (69.6%), SHP (small-hydro power) potential of 19749 MW (13.38%), Biomass power potential of 17,538 MW (11.88%) and 5000 MW (3.39%) from bagasse-based cogeneration in sugar mills.
- The geographic distribution of the estimated potential of renewable power as on 31.03.2014 reveals that Gujarat has the highest share of about 25.04% (36,956 MW), followed by Karnataka with 13.08% share (19,315 MW) and Tamil Nadu with 11.17% share (16,483 MW), mainly on account of wind power potential.
- The availability of crude oil in the country increased from 131.60 MTs during 2005-06 to 227.03 MTs during 2013-14.During this period crude oil production increased from 32.19 MTs to 37.79 MTs and the net import increased from 99.41 MTs to 189.24 MTs during period from 2005-06 to 2013-14. There was 1.96% increase in availability of crude oil during 2013-14 over 2012-13.





(iv) Refineries of crude oil

- As on 31.03.14 there were a total of 22 refineries in the country out of these 17 were in the Public Sector, 3 in the private sector and 2 in joint venture.
- The Refinery production (crude throughput) achievement was 222.497 MMT during 2013-14 which marks net increase of 1.5% over 2012-13 (219.212 MMT)
- Capacity utilization of the refineries was 101.9% during 2012-13 which increased to 103.5% during 2013-14. In the Public Sector the maximum increase in capacity utilization (12.9%) was at ONGC, Tatipaka, Andhra Pradesh.

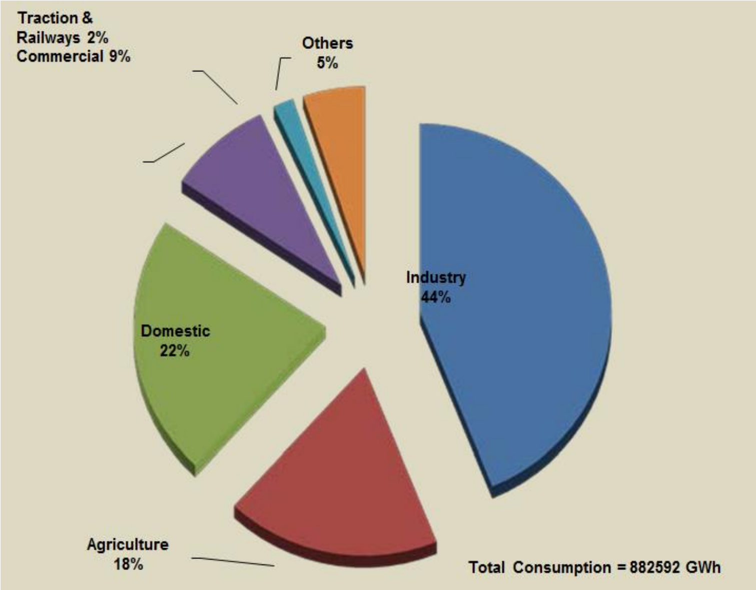
- In the Private Sector the highest increase (6.8%) in capacity utilization was at RIL(SEZ), Jamnagar, Gujarat.
- Indian Oil Corporation, the state owned corporation had highest refining capacity of 53,126 TMTY. All units of IOC together processed 53,126 TMT during 2013-14 as compared to 54,649 TMT during 2012-13. The capacity utilization of these refineries was 98% during 2013-14 as against 100.8% during 2012-13.
- All the private refineries taken together processed 88,229 TMT during 2013-14 as compared to 88,273 TMT during 2012-13. The capacity utilization of these refineries during 2012-13 and 2013-14 was constant i.e. 110.3%.

5. Explain in brief about the energy sources with special reference to Indian content.

(April/ May 2014)(April 2013)

Overall Production and Consumption

India is both a major energy producer and consumer. India became the world's third largest producer of electricity in the year 2013 with 4.8% global share in electricity generation surpassing Japan and Russia and as the world's fourth greatest energy consumer after China, USA and Russia. Thus, India is a net energy importer, mostly due to the large imbalance between oil production and consumption. The **India** had an installed capacity of 281.423 GW as of 30 November 2015,Renewable Power plants constituted 28% of total installed capacity and Non-Renewable Power Plants constituted the remaining 72%. The Sector wise energy consumption during 13-14 is shown in figure below.



Installed Power Station Capacity in India as of July 31, 2015									
Sector	**Thermal (MW)**				**Nuclear (MW)**	**Renewable (MW)**			**Total (MW)**
	Coal	**Gas**	**Diesel**	**Sub-Total Thermal**		**Hydel**	**Other Renewable**	**Sub-Total Renewable**	
Central	48,880.00	7,519.73	-	56,399.73	5,780.00	11,491.42	-	11,491.42	73,671.15
State	59,200.50	6,974.42	438.57	66,613.49	-	27,482.00	1,919.31	29,401.31	96,014.80
Private	59,627.38	8,468.00	554.96	68,650.34	-	3,024.00	34,551.33	37,575.33	106,225.67
Total	**167,707.88**	**22,962.15**	**993.53**	**191,663.56**	**5,780.00**	**41,997.42**	**36,470.64**	**78,468.06**	**275,911.62**

AVAILABILITY OF PRIMARY ENERGY RESOURCES

A. Conventional

(i) Fossil fuel India has vast reserves of coal, **the fifth largest in the world after USA, Russia, China and Australia.** According to a rough estimate, the total recoverable coal in India is **60.6 billion tonne, about 7% of the world's total**. With the present rate of consumption, India will have enough coal for about 300 years. Indian coal has high ash content (1%). The states of **Jharkhand, Odisha, Chhattisgarh, West Bengal, Madhya Pradesh, Andhra Pradesh and Maharashtra account for more than 99% of the total coal reserves** in the country. We have only 0.6% of the world's oil and gas reserves. Oil and gas represents over 40% of the total energy consumption in india. About 35% of oil needs are met through domestic production and the balance through imports. The estimated reserves of **crude oil** in India as on 31.03.2014 stood at **762.74 million(10^6) tons** (MT) ,enough to last about 22 years at the present rate, if no further discovery is made. The maximum reserves are found in the **Western Offshore** followed by Assam. The estimated reserves of **natural gas** in India as on 31.03.2014 stood at **1427.15 billion cubic meters (BCM)**, whereas the maximum reserves of Natural Gas are in the Eastern Offshore followed by Western offshore.

(ii) **Hydro resources:** India is the 6th largest producer of hydroelectric power. the list The present installed capacity as on July 31, 2015 is **41,997.42 MW** which is 15.22% of total electricity generation in India. Huge installation cost, environmental and social problems are major difficulties in its development.

(iii) India has modest reserves of uranium, mostly located at, Jharkhand, Andhra Pradesh. Out of the total electrical power generation, 2.21% is being generated by nuclear means. The power generation from nuclear power plant is **5,780.00MW by the year 2015.**

- Thorium is available in abundance in India in the form of monazite (ore) in the sand beaches of Kerala. The economically viable reserve of thorium in India is estimated at 3,00,000 tonnes, which is 25% of the world's thorium reserves. Thorium is a fertile material, which is converted into a fissionable material U^{233} in an FBR. The U^{233} so obtained may be used in a normal thermal reactor such as PHWR.

List of top three nuclear power plants in India

- Tarapur is the largest nuclear power station in India having a total capacity of 1400 MW.
- Rajasthan Atomic Power Station-1180 MW
- Kudankulam Nuclear Power Plant- 1000MW

Kudankulam Nuclear Power Plant is a nuclear power station of the southern Indian state of Tamil Nadu. It constructed first reactor plant (1000MW) critically in 13th July 2013.Another new plant of 1000 MW is under construction.

B. Non-Conventional

Located in the tropical region, India is endowed with abundant renewable energy resources, i.e, solar, wind and biomass including agricultural residue which is perennial in nature. Harnessing these resources is the best suited to meet the energy requirement in rural areas in a decentralized manner. India has the potential of generating more than **1,47,615 MW** from non-conventional resources. Up to July 31,2015, the power is produced from renewable source is **78,468.06 MW** which is about 12.14% of the total installed electrical power generation capacity. The current status of various resources are given in table

(i) Wind Energy

The highly successful wind power programme in India was initiated in 1983-84 and is entirely market driven. This sector has been growing at over 35% in the last three years. India has the fifth largest installed wind power capacity in the world

after USA, China, Spain and Germany. The current installed capacity for wind power stands at 23,447.5 MW, and is located in Tamil Nadu, Gujarat, Maharashtra and Rajasthan.

(ii) Solar energy

India receives a solar energy equivalent of more than 4346.82 MW per year, which is far more than its total annual consumption. The daily global radiation is around 4 to 7 kWh/square meter/day across India. Though density is low and the availability is not continuous, it has become possible to harness this abundantly available energy very reliably for many purposes by converting it to usable hear or through direct generation of electricity. India is endowed with rich solar energy resource. India receives the highest global solar radiation on a horizontal surface. The first Indian solar thermal power project (2X50MW) is in progress in Phalodi Rajasthan. Land acquisition is a challenge to solar farm projects in India. Gujarat is leader in solar power in India, it accounts for nearly 66% of India's total solar power. The plant is located in the Solar Park came up at Charanka village in the Patan district of the state. It has total of 500 MW capacities which includes both solar energy and wind energy. The Solar Park has received **10th Wartsila-Mantosh Sondhi Award** for its contribution to the Indian energy sector.

(iii) Biomass Energy

A large quantity of biomass is available in our country in the form of dry waste like agro residues, fuel wood, twigs, etc., and wet wastes like cattle dung, organic effluents, sugarcane bagasse, banana stems, etc. The potential for generation of electric power is 1,365.20 MW from biomass and 2,800.35 from bagasse through cogeneration. The potential from urban waste is 107.58 MW. Also, there is a vast scope for production of bio-diesel from some plants. These plants require little care, can be grown on fallow land and can survive in harsh climatic conditions.

(iv) Small Hydro Resources

Hydro resources of capacity less than 25 MW are called small, less than 1MW are called mini and less than 100KW are called micro hydro resources. The total potential is 20,000 MW. out of which 3,990.83 MW has been realized by approximately 611 plants.

(v) Geothermal Energy

The potential in geothermal resources in the country is 10,000MW. As a result of various resource assessment studies/surveys, nearly 340 potential hot springs have been identified throughout the country. Only some of them are considered suitable for power generation. The reservoirs suitable for power generation have been located in Tattapani. Hot-water resources are located at Badrinath, Kedarnath and few other locations in the Himalayan ranges and elsewhere. They are being used mostly for heating purposes and very little has been developed. Andaman and Nicobar arc is the only place in India where volcanic activity geo-thermal energy is present.

India is planned to have first geothermal power plant with 10,600 MW of potential in the geothermal provinces at Chattishgar.

(vi) Ocean Tidal Energy

There is no function tidal plant at present and the total potential has been estimated to 9,000MW. Three sites have been identified.

West Coast

- Gulf of Cambay (7000 MW)
- Gulf of Kutch (1200 MW)

East Coast

The Ganges Delta in the Sunderbans in West Bengal for small scale tidal power development. Estimates peg the potential in this region to be about 100 MW.

The Gujarat state government has approved Rs 25 crore for setting up the 50 MW plant at the Gulf of Kutch. The government has signed a MOU with Atlantis Resource Corporation to setup the plant. The Gujarat government last year also approved a 10 MW tidal energy plant proposed by Urja Global Limited in association with a US-based company Ocean Energy Industries. MNRE sanctioned a demonstration project for setting up 3.75 MW capacity tidal energy power plant at the Durgaduani Creek in Sunderbans region.

(vii) Ocean Wave and OTEC Resources

The potential along the 6000 Km of India's coast is estimated to be about 40,000 MW – these are preliminary estimates. This energy is however less intensive than what is available in more northern and southern latitudes.

A 150KW pilot plant has been installed at Vizhingum harbour near Thiruvananthapuram, Kerala. The average potential for Indian coasts has been estimated at around 0.02MW/m of wave front. There is a proposal for an OTEC plant at the Minicoy Island of Lakshadweep.

Emerging technologies like 'fuel cell' and 'hydrogen energy' are suited for stationary and portable power generation, which suits transportation purposes. In view of the growing importance of the fuel cells and hydrogen, a National Hydrogen Energy Board has been created. The board will provide guidance for the preparation and implementation of the National Hydrogen Energy Road Map, covering all aspects of hydrogen energy starting from production, storage, delivery, application, safety issues, codes and standards, public awareness and capacity buildings. Eco-friendly electric vehicles for transportation are being fields tested for improving their performance.

6. Explain the limitations of conventional sources of energy.

LIMITATIONS OF CONVENTIONAL SOURCES OF ENERGY

COAL

Advantages

- One of the most abundant energy sources
- Versatile; can be burned directly, transformed into liquid, gas, or feedstock
- Inexpensive compared to other energy sources
- Can be used to produce ultra-clean fuel
- Can lower overall amount of greenhouse gases (liquification or gasification)
- Leading source of electricity today
- Reduces dependence on foreign oil
- By-product of burning (ash) can be used for concrete and roadways

Drawbacks

- Source of pollution: emits waste, SO_2, Nitrogen Oxide, ash
- Coal mining mars the landscape
- Liquification, gasification require large amounts of water
- Physical transport is difficult
- Technology to process to liquid or gas is not fully developed
- Solid is more difficult to burn than liquid or gases
- High water content reduces heating value
- Dirty industry—leads to health problems
- Dirty coal creates more pollution and emissions

NATURAL GAS

Advantages

- Burns clean compared to cola, oil (less polluting)
- 70% less carbon dioxide compared to other fossil fuels
- helps improve quality of air and water (not a pollutant)
- does not produce ashes after energy release
- has high heating value of 24,000 Btu per pound
- inexpensive compared to coal
- no odor until added

Drawbacks

- not a renewable source
- finite resource trapped in the earth (some experts disagree)
- inability to recover all in-place gas from a producible deposit because of unfavorable economics and lack of technology (It costs more to recover the remaining natural gas because of flow, access, etc.)

WATER POWER

Advantages

- Provides water for 30-30% of the world's irrigated land
- Provides 19% of electricity
- Expands irrigation
- Provides drinking water
- Supplies hydroelectric energy (falling water used to run turbines)
- Easier for third world countries to generate power (if water source is available)
- It is cheaper

Drawbacks

- Destabilizes marine ecosystems
- Water wars (up river and down river; e.g., the water war between Georgia, Alabama, and Florida is ongoing)
- Dam building is very costly
- People have to relocate
- Some dams have to be torn down (Some older ones arenot stable.)
- Restricted to areas with flowing water
- Pollution affects water power
- Flooding of available land that could be used for agriculture

OIL

Advantages

- Oil is one of the most abundant energy resources
- Liquid form of oil makes it easy to transport and use
- Oil has high heating value
- Relatively inexpensive
- No new technology needed to use

Disadvantages

- Oil burning leads to carbon emissions
- Finite resources (some disagree)
- Oil recovery processes not efficient enough—technology needs to be developed to provide better yields
- Oil drilling endangers the environment and ecosystesm
- Oil transportation (by ship) can lead to spills, causing environmental and ecological damage (major oil spill near Spain in late Fall 2002)

NUCLEAR POWER

Advantages

- Clear power with no atmospheric emissions
- Useful source of energy
- Fuel can be recycled
- Low cost power for today's consumption
- Viable form of energy in countries that do not haveaccess to other forms of fuel

Disadvantages

- Potential of high risk disaster (Chernobyl)
- Waste produced with nowhere to put it
- Waste produced from nuclear weapons not in use
- Earthquakes can cause damage and leaks at plants
- Contamination of the environment (long term)
- Useful lifetime of a nuclear power plant
- Plant construction is highly politicized

7. Explain about principle of energy conservation and also the economics of energy Conservation. **(Nov 2011)(Nov/Dec 2014)(Nov 2012))(Nov 2013))(April 2015)(April 2013)**

An economic concept of energy

It is impossible to forecast future economic trends accurately except in one respect: if a non – renewable asset is being used up, its price is bound to go up relative to everything else.

The vast bulk of the energy used in the world today is in the form of non-renewable oil, natural gas and coal. These resources were laid down many millions of years ago and are at present being consumed at the rate of almost 9 billion tonnes of coal equivalent or 0.32 million petajoules (1 petajoule = 10 joules) per annum. This compares with proved recoverable world resources of 20.3 million petajoules of coal and 11.2 million petajoules of oil and natural gas. The advanced capitalist industrial countries, which make upto 15.75 percent of the world's population, consume 54.5 percent of these 0.32 million petajoules each year. It is unlikely that the world's under developed countries are going to improve their living standard if they did, the annual world's energy demand would rise to 1.11 million petajoules each year even if the living standards in all western countries remained constant.

So we must conserve energy by all possible means. For example, glass works produce waste heat at between 400 and 500^0C. This is quite sufficient to raise intermediate pressure steam for running back pressure turbines to produce electricity and heat in the form of low pressure steam at, say 120^0C. This, in its turn could be used to evaporate moisture from agriculture products. The water vapour obtainable from such processes would probably be condensed to provide warm water at about 60^0C. This could be employed for space heating or for the supply of heat at fish farms or green houses.

Principles of Energy Conservation and Energy Audit

Energy conservation means reduction in energy consumption but without making any sacrifice of quantity and quality of production in other words, for the same energy consumption, higher production. It is therefore impressive that electricity which is in shortage be utilised efficiently and the areas, where the energy is wastefully used are to be identified and corrective measures are searched for adoption. This could be done by "energy audit". Energy Audit is a technical survey of a plant in which the machine wise/ section wise/department wise pattern of energy consumption is studied and attempts to balance the total energy input correlating with production. As a result of study the areas where the energy is wastefully used and the improvements are felt are identified and corrective measures are recommended for adoption on short term/long term basis giving priorities so that the overall plant efficiency could be improved.

Energy conservation can be defined as the substitution of energy with capital, labour, material and time. The two principles governing energy conservation policies are maximum thermodynamic efficiency and maximum cost effectiveness in energy use.

An energy audit helps us to understand more about the ways different energy sources are used in the industry and helps us to identify areas where waste can occur and where scope for improvement may be possible. Energy audit broadly covers the following questions:

(i) How much energy are we consuming?
(ii) Where is the energy consumed?
(iii)How efficiently is the energy consumed?
(iv)Can there be improvements in energy use?

Types of energy audit:

The primary objective of the energy audit is to determine ways to reduce energy consumption per unit of product output to lower operating cost. The energy audit can be two types:

1. Preliminary audit
2. Detailed audit

The action plan towards the achievement of energy conservation through energy audit may be drawn up in to three phases

1. Short term
2. Medium term
3. Long term.

Preliminary audit:

Preliminary audit is carried out in the limited time i.e from 1 to 10 days and it high light the energy cost and wastages in the major equipment and processes. It also gives the major energy supplies and the demanding accounting. The questionnaire containing the industrial details of energy consumption process carried out, energy need to unit product, load dataset must be completed before the pre-audit visit. The financial report regarding the industrial audit will be prepared within two weeks of time.

Detailed audit:

Detailed audit includes engineering recommendations and well defined projects with priorities. It accounts for the total energy utilised in plants. It involves detailed engineering for options to reduce energy cost/consumption. The duration for visit would be 1 to 10 weeks. It requires advance notice to the departmental head arranging for office and secretarial support. The final report would be prepared within the month of audit.

The short term action:

This plan requires no capital investment or least investment to avoid energy wastages and minimizing non-essential energy users and improving the system efficiency through improved maintenance program.

The medium term action:

Plan requires little investment to achieve investment or least investment to achieve efficiency improvement through modifications of existing equipment and other operations.

The long term action:

Plan is aimed to achieve economy through latest energy saving techniques and innovations. The capital investments are required to be studied thoroughly while finalising the long term action plan.

8. Explain about waste heat recovery. **(April/May 2014))(April/May 2012) (Nov 2012)**

Waste heat is heat, which is generated in a process by way of fuel combustion or chemical reaction, and then "dumped" into the environment even though it could still be reused for some useful and economic purpose. The essential quality of heat is not the amount but rather its "value". The strategy of how to recover this heat depends in part on the temperature of the waste heat gases and the economics involved.

Large quantity of hot flue gases is generated from Boilers, Kilns, Ovens and Furnaces. If some of this waste heat could be recovered, a considerable amount of primary fuel could be saved. The energy lost in waste gases cannot be fully recovered. However, much of the heat could be recovered and loss minimized.

Depending upon the type of process, waste heat can be rejected at virtually any temperature from that of chilled cooling water to high temperature waste gases from an industrial furnace or kiln. Usually higher the temperature, higher the quality and more cost effective is the heat recovery. In any study of waste heat recovery, it is absolutely necessary that there should be some use for the recovered heat. Typical examples of use would be preheating of combustion air, space heating, or pre-heating boiler feed water or process water. With high temperature heat recovery, a cascade system of waste heat recovery may be practiced to ensure that the maximum amount of heat is recovered at the highest potential. An example of this technique of waste heat recovery would be where the high temperature stage was used for air pre-heating and the low temperature stage used for process feed water heating or steam raising.

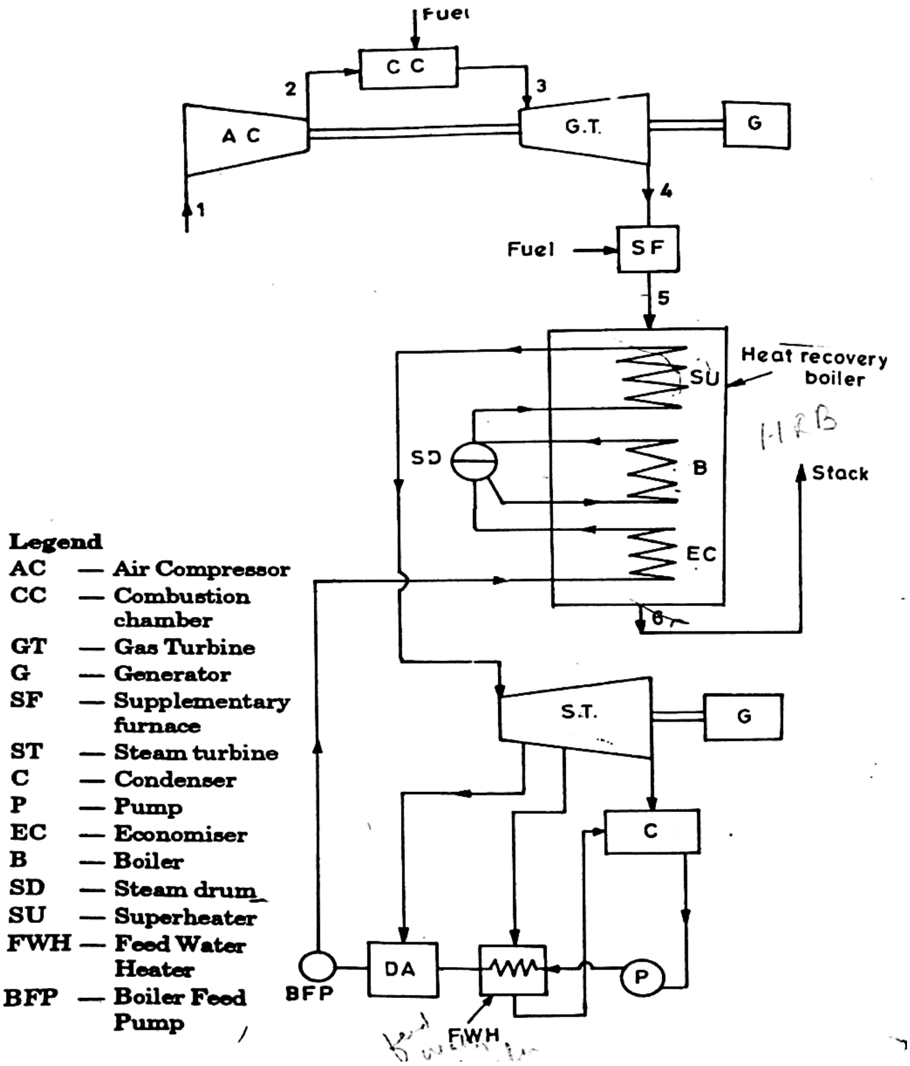


Figure above shows a schematic flow diagram of such a combined cycle. A simple gas turbine cycle, consisting of air compressor, combustion chamber and gas turbine is used with the turbine exhaust gas going to heat a heat recovery boiler to generate superheated steam. That steam is used in a standard steam cycle, which consists of turbine, condenser, pump, closed feed water heaters and deaerating heaters. The heat recovery boiler consists of an economiser, boiler, steam drum and super heater. The gas leaves the heat recovery boiler to the stack. Both gas and steam turbines drive electric generators.

9. Explain the economics of energy conservation in detail

ECONOMICS OF ENERGY CONSERVATION

- Reduced dependence on non-renewable sources of energy: Based on current known reserves and consumption of these fuels, the following amount of each fossil fuel remains available as of 2003:
  - Oil: Approximately 1,000 billion barrels, enough to last 38 years
  - Natural Gas: Approximately 5,400 trillion cubic feet, enough to last 59 years
  - Coal: Approximately 1,000 billion metric tons, enough to last 245 years

- Conservation protects national energy security by reducing our dependence on foreign sources of oil.
- Protects the economy and consumers from possible price fluctuations and from energy service disruptions due to natural disasters or other causes.
- The increasing demand for electricity and natural gas requires your utility to find new supplies of energy. Most new supply options require a great deal of money up front, which increases you utility bills.
- Studies show that utility or state investment in energy efficiency helps the local economy. Instead of importing natural gas and electricity supply from outside of your community, energy efficiency relies on domestic and local companies and retailers to provide energy management services and energy-saving products.
- Energy efficiency programs provide customers with home improvements that enhance home comfort and increase property values for homeowners and businesses.

10. Explain Dispersed Generation in detail.

Dispersed Generation - Future Evolution of Distribution System

Competition as a result of deregulation is driving utilities and consumers to seek out alternate means to reduce the cost of electricity. The centralized model is losing its viability on the account of large-scale investment and deregulation. It becomes an uphill task to supply electrical power with high reliability in the conventional power system structure. The utility industry is expected to shift generation slightly away from the traditional central station philosophy to decentralized generation.

Decentralized Generation

Decentralized Generation is the production of electricity at or near the point of use, irrespective of size, fuel or technology. Decentralized electric generation will reduce capital investment, lower the cost of electricity, reduce pollution, reduce production of greenhouse gas, and decrease vulnerability of the electric system to extreme weather and terrorist attacks. Decentralized Generation can be distributed or dispersed and can be powered by a wide variety of fossil fuels.

- **Distributed** power generation is any small-scale power generation technology that provides electric power at a site closer to customers than central station generation.
- **Dispersed** generation is a decentralized power plant, feeding into the distribution level power-grid and typically sized between 10 and 150 MW.

Distributed generation is used mainly for onsite power generation. Dispersed generation is strategically located on the transmission grid to overcome bottlenecks in the transmission and distribution system and to improve the stability of the system.

Features of Dispersed Generation

Dispersed generation reduces both power transfers between regions of the power system and power imbalance in each region. Dispersed generation also allows for a uniform distribution of the overall system by responding fast to demand variation. Dispersed generation offers more flexibility and can be dispatched in incremental blocks of power as needed. It provides reliability and stability to the system. Total failure can be avoided when the load centres are supported by dispersed generation. A major outage such as the one experienced in August 2003 could have been avoided with the help of dispersed generation powered by reciprocating engines, by bringing power back online within 10 minutes.

PONDICHERRY UNIVERSITY QUESTIONS

2 MARKS

1. Define primary energy sources. **(Nov 2011) (April 2015)**
2. List out the various conventional and non-conventional power plant. **(April/May 2012) (April/May 2014)**
3. What are the Secondary energy Sources? **(April/May 2014)**
4. What are the advantages of renewable energy? **(Nov 2012) (April/May 2014)**
5. State the world wide status of India in coal energy. **(April/May 2012)**
6. List out the availability of nuclear fuel in India. **(April 2013)**
7. Write the renewable energy sources utilized in India. **(Nov 2012) (Nov/Dec 2014)**
8. Name any two types of nuclear fuels used as conventional energy sources. **(Nov 2011)**
9. Define energy conservation? **(April 2015) (April/May 2014)**
10. What are the principles of energy conservation? **(Nov 2013) (Nov/Dec 2014)**
11. What are the steps to be followed for energy conservation? **(April 2013)**
12. What are called as secondary fuels? **(Nov 2013)**
13. List out the sources of Biogas. **(Nov 2013)**

11 MARKS

1. What are the prospects of renewable energy sources? **(Nov 2012) (April/May 2014) (April 2013)**
2. Explain about the various conventional energy sources and their availability? **(April/May 2012)**
3. Explain in detail about the availability of oil, hydro, natural gas and coal power. **(Nov 2012) (April 2015) (April 2013)**
4. Explain in brief about the energy sources with special reference to Indian content. **(April/ May 2014) (April 2013)**
5. Explain in detail about resources for power generation in India. **(April/May 2014)**
6. Explain about principle of energy conservation and also the economics of energy Conservation. **(Nov 2011)(Nov/Dec 2014)(Nov 2012))(Nov 2013))(April 2015)(April 2013)**
7. Explain about waste heat recovery. **(April/May 2014) (April/May 2012) (Nov 2012)**

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

Subject Name: Renewable Energy Sources

Subject Code: EE E12

UNIT I

SOLAR ENERGY AND APPLICATIONS

Solar radiation-Principles of solar energy collection-Types of collector–Characteristics and Principles of different types of collectors and their efficiencies,

Solar Energy applications-water heaters, air heaters, solar cooling; solar drying and power generation -solar tower concept (solar plant) -solar pump,

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2- MARKS

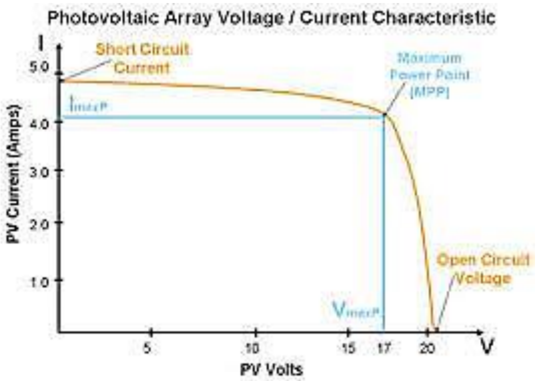
1. **What are the components of solar energy?** **(April 2014)**

Classify the methods of solar energy storage.

a. Solar pond
b. Rock bed storage
c. Solar energy is stored in Battery in the form of chemical energy

2. **Define solar constant?** **(April 2015)(Nov 2013) (November 2012)**
   - It is the rate at which solar energy arrives at the top of atmosphere.
   - This is the amount of energy received in unit time on a unit area perpendicular to the sun's direction at the mean distance of the earth from the sun.
   - According to NASA the solar constant is expressed in following three ways:
     – 1.353 Kilowatts per square meter or 1353 watts per square meter
     – 429.2 Btu per square foot per hour
     – 1164 kcal per square meter per hour

3. **Draw the VI characteristics of Solar PV cell.** **(April/May 2012)**



4. **Define solar energy.(November 2011)**

Solar energy in the form of solar radiation that penetrates the earth the earth's atmosphere and reaches the surface differs in amount. Solar radiation radiations that has absorbed or scattered and reaches the ground directly from the sun is called "Direct Radiation" or "Beam Radiation". Diffuse Radiation is that solar radiation received from the sun after its direction has been changed by reflection and scattering by the atmosphere

5. **What is concentration ratio?**

Concentration ratio is defined as the ratio between the aperture area and the receiver absorber area of the collector.

6. **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)

7. **List any four applications of solar collectors.(November 2012)**
   1. Solar water heating
   2. Solar space heating systems
   3. Solar refrigeration
   4. Industrial process heat systems

8. **List the four important solar systems.**
   1. Low temperature cycles using flat plat collector or solar pond
   2. Power tower or central receiver system
   3. Distributed collector system
   4. Concentrating collectors for medium and high temperature cycle

9. **List the advantages of solar Energy.** **(Nov 2013)**
   1. Solar energy is free from pollution
   2. They collect solar energy optically and transfer it to a single receiver, thus minimizing thermal-energy transport requirements
   3. They typically achieve concentration ratios of 300 to 1500 and so are highly efficient both in collecting energy and converting it to electricity.
   4. The plant requires little maintenance or help after setup
   5. It is economical

10. **List any four disadvantages of solar energy.**
    1. Available in day time only
    2. Need storage facilities
    3. It needs a backup power plant
    4. Keeping back up plants hot includes an energy cost which includes coal burning

11. **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 voltaic cell) to generate electrical energy.

12. **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.

13. **What is solar collector?** **(April 2013)**

    Solar energy is 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 voltaic cell) to generate electrical energy.

14. **Name few applications of solar energy.** **(Nov 2012)**
    1. Solar water heating
    2. Solar space heating systems
    3. Solar refrigeration
    4. Industrial process heat systems

15. What are the applications of solar water heater? **(November 2012)**

1. **Domestic:** Flats, Bungalows and Apartments.
2. **Commercial:** Hotels, Hospitals, Hostels and Dormitories.
3. **Industrial:** Process Industries, Preheating boiler feed water. In domestic sector, hot water is used for bathing, washing of clothes &utensils.

16. What are the applications of solar air heaters? **(Nov 2012)**

- Space heating applications
- Process heat applications
- Night cooling applications
- Ventilation applications

17. Define PV effect. **(April 2012)**

The photovoltaic effect is the creation of voltage or electric current in a material upon exposure to light and is a physical and chemical phenomenon.

18. Define solar altitude angle. **(April 2012)**

Solar altitude refers to the angle of the sun relative to the Earth's horizon. Solar altitude is measured in degrees. The value of the solar altitude varies based on the time of day, the time of year and the latitude on Earth. Regions close to the equator have a higher solar altitude than regions near the Earth's poles.

19. What are the two basic types of instruments employed for solar radiation measurements. **(Nov 2013)**

Two basic types of instruments are used in measurements of solar radiation. These are:
1. Pyranometer: An instrument used to measure global (direct and diffuse) solar radiation on a surface. This instrument can also be used to measure the diffuse radiation by blocking out the direct radiation with a shadow band.
2. Pyrheliometer: This instrument is used to measure only the direct solar radiation on a surface normal to the incident beam. It is generally used with a tracking mount to keep it aligned with the sun.

20. Define collector efficiency. **(Nov 2012)**

The Solar Rating and Certification Corporation (SRCC) currently rates solar collectors in five categories according to the difference between collector inlet fluid temperature (Ti) and the ambient air temperature (Ta).

All the SRCC data is calculated from efficiency equations acquired from testing collectors at certified test laboratories. The efficiency is defined as:

Efficiency = What you get out / What you put in

11 MARKS

1. Explain about Solar energy basics?

The photovoltaic effect is the electrical potential developed between two dissimilar materials when their common junction is illuminated with radiation of photons. The photovoltaic cell, thus, converts light directly into electricity. The pv effect was discovered in 1839 by French physicist Becquerel. It remained in the laboratory until 1954, when Bell Laboratories produced the first silicon solar cell. It soon found application in the U.S. space programs for its high power capacity per unit weight. Since then it has been an important source of power for satellites. Having developed maturity in the space applications, the pv technology is now spreading into the terrestrial applications ranging from powering remote sites to feeding the utility lines.

Energy from the sun:

The physics of the PV cell is very similar to the classical p-n junction diode. When light is absorbed by the junction, the energy of the absorbed photons is transferred to the electron system of the material, resulting in the creation of charge carriers that are separated at the junction. The charge carriers may be electron-ion pairs in a liquid electrolyte or electron hole pairs in a solid semiconducting material. The charge carriers in the junction region create a potential gradient, get accelerated under the electric field and circulate as the current through an external circuit. The current squared times the resistance of the circuit is the power converted into electricity.

The remaining power of the photon elevates the temperature of the cell. The origin of the photovoltaic potential is the difference in the chemical potential, called the Fermi level, of the electrons in the two isolated materials. When they are joined, the junction approaches a new thermodynamic equilibrium. Such equilibrium can be achieved only when the Fermi level is equal in the two materials. This occurs by the flow of electrons from one material to the other until a voltage difference is established between the two materials which have the potential just equal to the initial difference of the Fermi level. This potential drives the photocurrent.

Solar constant:

The solar constant is the rate at which the energy is received upon a unit surface, perpendicular to the sun's direction, in free space at the earth's mean distance from the sun. It is generally expressed in calories per square centimetre per minute and in these units has usually been considered to lie in the range of 1.89 to 1.95.

Solar Spectrum:

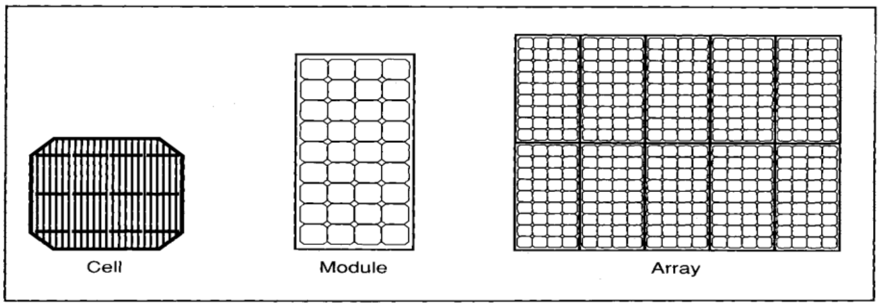
The energy irradiation comes in the form of electromagnetic waves of a wide spectrum. Longer wavelengths have less energy (for instance infrared) than shorter ones such as visible light or UV. The spectrum can be depicted in a graph, the spectral distribution, which shows the relative weight of individual wavelength plotted over all wavelengths, measure in W/m (wavelength).

Clarity index:

The ratio of the solar radiation arriving at the earth's surface to extra-terrestrial radiation. The monthly average clearness index is the ratio of monthly average daily solar radiation at the surface of the monthly average daily extra-terrestrial radiation. K_T varies from place to place from about 0.3 for very overcast climates to 0.8 for very sunny places.

Solar module:

The solar cell described above is the basic building block of the pv power system. Typically, it is a few square inches in size and produces about one watt of power. For obtaining high power, numerous such cells are connected in series and parallel circuits on a panel (module) area of several square feet fig. below.



The solar array or panel is defined as a group of several modules electrically connected in series-parallel combinations to generate the required current and voltage. Fig shows the actual construction of a module in a frame that can be mounted on a structure. Mounting of the modules can be in various configurations as seen in Fig. In the roof mounting, the modules are in the form that can be laid directly on the roof. In the newly developed amorphous silicon technology, the PV sheets are made in shingles that can replace the traditional roof shingles on one-to-one basis, providing a better economy in the material and labour.

2. **Explain about VI characteristics of a solar cell.** **(Nov/Dec 2014)**

The well known characteristic of an ordinary silicon pn junction is shown in figure below as a dark characteristic with the junction not illuminated. Mathematically this is given by

$$I = I_o\{\exp\left(\frac{V}{V_T}\right) - 1\}$$

Where I_o is the reverse saturation current,

$V_T = \frac{kT}{q}$

where k is Boltzman's constant

T is temperature in ^oK and

q is charge of an electron

When the pn junction is illuminated, the characteristic gets modified in shape and shifts downwards as the photon generated component is added with reverse leakage current a shown in figure. The above diode equation is modified as

$$I = -I_{sc} + I_o\{\exp\left(\frac{V}{V_T}\right) - 1\}$$

When the junction is short circuited at its terminals, V becomes zero and a finite current I=-I_{sc} flows through the external path emerging from the p side. I_{sc} is known as short circuit current and its magnitude will depend on solar radiation. Now, a voltage source is inserted in the external path with positive polarity on the p side. As the magnitude of this external voltage is increased from zero, the current tarts decreasing. The value V_{oc} of this voltage at which the current becomes zero is known as open circuit voltage.

Thus $V_{oc} = V_T ln\left\{\left(\frac{I_{sc}}{I_o}\right) + 1\right\}$

Mathematically, the I-V characteristic of a solar cell may be written as;

$$I = I_{sc} - I_o\{\exp\left(\frac{V}{V_T}\right) - 1\}$$

In order to obtain as much energy as possible from the rather costly PV cell, it is desirable to operate the cell to produce maximum power. The maximum power (P_m) point can be obtained by plotting the hyperbola defined by VxI= constant, such that it is tangential to the I-V characteristic. The voltage and current corresponding to this point are peak point voltage, V_m and peak point current I_m respectively. Thus, there is only one point on the characteristic at which it will produce the maximum electrical power under the incident illumination level. Operating at other than the maximum power it will mean that the cell will produce a lesser electrical power and more thermal power. The maximum power point is also readily found by simply plotting cell power versus sell voltage as shown in figure. If a rectangle of maximum possible area is inscribed in the area defined by the I-V characteristics and I-V axes, it meets the characteristics at the peak point as shown in figure. Closeness of the characteristics to the rectangular shape is a measure of the quality of the cell. An idea cell would have a perfect rectangular characteristic. Therefore, the 'fill factor',FF which indicates the quality of a cell, is defined as the ratio of the peak power to the product of open circuit voltage and short circuit current i.e.

$$FF = \frac{V_m I_m}{V_{oc} I_{sc}}$$

An ideal cell will have a fill factor of unity. In order to maximize the fill factor, the ratio of the photocurrent to reverse saturation current should be maximized while minimizing internal series resistance and maximizing the shunt resistance. Typically, its value for a commercial silicon cell is in the range of 0.5 to 0.83.

The conversion efficiency

$$\eta = \frac{V_m I_m}{solarpower} = \frac{FFV_{OC} I_{SC}}{solarpower}$$

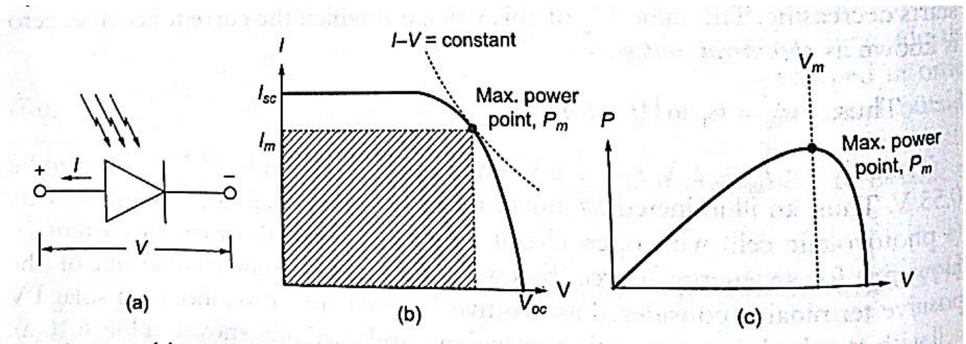


Fig. 6.10 (a) Schematic symbol of a photovoltaic cell (b) I– V characteristic, maximum power point (c) P–V characteristic

3. Draw the schematic diagram of a solar PV plant and explain Solar PV plant? Explain the block diagram and working of solar power generation. Describe construction and working of solar cell. (April 2013)(April/May 2012)(Nov 2012)(April/May 2014)

The solar thermal power system collects the thermal energy from solar radiation and uses at high or low temperature. The low temperature applications include water and space heating for commercial and residential buildings. Producing electricity using the steam-turbine-driven electrical generator is example for a high temperature application. The technology of generating electrical power using the solar thermal energy has been demonstrated at commercial scale.

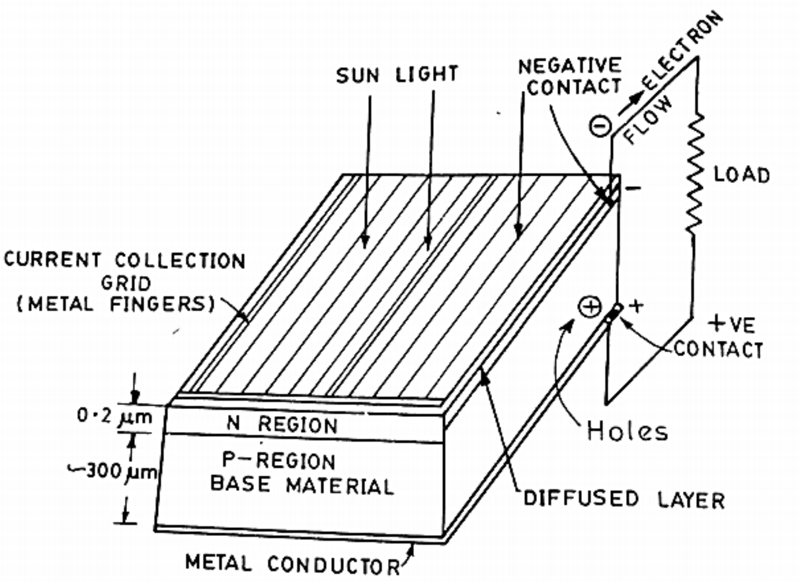


Fig. 5.6.1. Schematic view of a typical solar cell.

Fig. above shows the basic cell construction. For collecting the photocurrent, the metallic contacts are provided on both sides of the junction to collect electrical current induced by the impinging photons on one side. Conducting foil (solder) contact is provided over the bottom (dark) surface and on one edge of the top (illuminated) surface. Thin conducting mesh on the remaining top surface collects the current and lets the light through. The spacing of the conducting fibers in the mesh is a matter of compromise between maximizing the electrical conductance and minimizing the blockage of the light. In addition to the basic elements, several enhancement features are also included in the construction. For example, the front face of the cell has anti-reflective coating to absorb as much light as possible by minimizing the reflection. The mechanical protection is provided by the cover glass applied with a transparent adhesive.

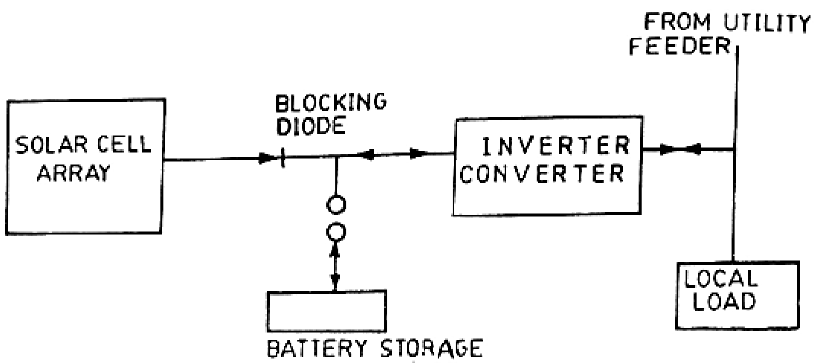


Fig. 5.6.5. Basic photovoltaic system integrated with power grid.

Fig. above shows the schematic of a large-scale solar thermal power station developed, designed, built, tested, and operated with the U.S. Department of Energy funding. In this plant, the solar energy is collected by thousands of sun-tracking mirrors called heliostats that reflect the sun's energy to a single receiver a top a centrally located tower. The enormous amount of energy focused on the receiver is used to generate high temperature to melt a salt. The hot molten salt is stored in a storage tank, and is used, when needed, to generate steam and drive the turbine generator. After generating the steam, the used molten salt at low temperature is returned to the cold salt storage tank. From here it is pumped to the receiver tower to get heated again for the next thermal cycle.

The usable energy extracted during such a thermal cycle depends on the working temperatures. The maximum thermodynamic conversion efficiency that can be theoretically achieved with the hot side temperature T_{Hot} and the cold side temperature T_{cold} is given by the Carnot cycle efficiency, which is as follows, where the temperatures are in absolute scale. The higher the hot side working temperature and lower the cold side exhaust temperature, the higher the plant efficiency of converting the captured solar energy into electricity. The hot side temperature T_{Hot} , however, is limited by the properties of the working medium. The cold side temperature T_{cold} is largely determined by the cooling method and the environment available to dissipate the exhaust heat.

A major benefit of this scheme is that it incorporates the thermal energy storage for duration in hours with no degradation in performance, or longer with some degradation. This feature makes the technology capable of producing high-value electricity for meeting peak demands. Moreover, compared to the solar photovoltaic, the solar thermal system is economical, as it eliminates the costly semiconductor cells.

4. Explain the different types of solar collectors and its efficiencies. **(Nov 2012) (Nov 2013)**

The different types of solar thermal panel collectors

Evacuated tube solar thermal systems

The **evacuated tube solar thermal system** is one of the most popular solar thermal systems in operation. An evacuated solar system is the **most efficient** and a common means of solar thermal energy generation with a rate of efficiency of 70 per cent. As an example, if the collector generates 3000 kilowatt hours of energy in a year then 2100 kilowatt hours would be utilised in the system for heating water. The rate of efficiency is achieved because of the way in which the evacuated tube systems are constructed, meaning they have excellent insulation and are virtually unaffected by air temperatures. The collector itself is made up of rows of insulated glass tubes that contain copper pipes at their core. Water is heated in the collector and is then sent through the pipes to the water tank. This type of collector is the most efficient, but also the most expensive.

There are two main types of tubes that are used inside the collector which are glass-glass and glass-metal. The glass-glass version uses two layers of glass fused together at both ends. The double glass tubes have a very reliable vacuum but reduce the amount of light that reaches the absorber inside. The double glass system may also experience more absorber corrosion due to moisture or condensation forming in the non-evacuated area of the tube. The second kind of tube is a glass-metal combination. The glass-metal combination allows more light to reach the absorber and reduces the chances of moisture corroding the absorber.

The cylindrical shape of evacuated tubes means that they are able to collect sunlight throughout the day and at all times in the year. Evacuated tube collectors are also easier to install as they are light, compact and can be carried onto the roof individually. What’s more, the tubes can be replaced individually if one becomes faulty, avoiding the need to replace the whole collector. The system is an efficient and durable system with the vacuum inside the collector tubes having been proven to last for over twenty years. The reflective coating on the inside of the tube will also not degrade unless the vacuum is lost.

Flat plate solar thermal systems

It is another common type of solar collector which have been in use since the 1950s. The main components of a flat plate panel are a dark coloured flat plate absorber with an insulated cover, a heat transferring liquid containing antifreeze to transfer heat from the absorber to the water tank, and an insulated backing. The flat plate feature of the solar panel increases the surface area for heat absorption. The heat transfer liquid is circulated through copper or silicon tubes contained within the flat surface plate.

Some panels are manufactured with a flooded absorber that involves having two sheets of metal and allowing the liquid to flow between them. Using a flooded absorber increases surface area and gives a marginal boost in efficiency. The absorber plates themselves are usually made from copper or aluminium and are painted with a selective heat coating which is much better at absorbing and retaining heat than ordinary paints. In an area that produces an average level of solar energy, the amount of energy a flat plate solar collector generates equates to around one square foot panel generating one gallon of one day's hot water.

The flat plate panel design utilises many different absorber configurations with the main design being the harp configuration. The harp design is usually used in low pressure thermosyphon systems or pumped systems. Other configurations include the serpentine which uses a continuous S shaped absorber and is used in compact hot water only systems which do not utilise space heating. There are also the flooded absorber systems and boundary absorbers which use multiple layers of absorber sheet where the heat is then collected in the boundary layer of the sheets.

Polymer flat plate collectors are an alternative to metal plate collectors. Metal plates are more prone to freezing whereas the polymer plates themselves are freeze tolerant so can dispense with antifreeze and simply use water as a heat transferring liquid. Any antifreeze that is added to the heat transfer liquid will reduce its heat carrying capacity at a marginal rate. A benefit of polymer plates is that they can be plumbed straight into an existing water tank removing the need for a heat exchanger which increases efficiency. Some polymer panels are painted with matte black paint rather than a selective heat coating. This is done to prevent overheating although high temperature silicone is now normally used to prevent overheating.

This design of solar panel is, overall, slightly less compact and less efficient when compared with an evacuated tube system, however this is reflected in a cheaper price. This design of solar can work well in all climates and can have a life expectancy of over 25 years.

Thermodynamic panels

Thermodynamic solar panels are a new development in solar thermal technology. They are closely related to air source heat pumps in their design but are deployed on the roof or walls like regular solar thermal panels and do not have to be south facing. The concept behind thermodynamic solar technology is that it acts like a reverse freezer and they differ from conventional solar thermal in that they do not use solar radiation to heat up heat transferring liquids.

The panels have a refrigerant passing through them which will absorb heat. The heat that passes through the panel will then in turn become a gas. The gas is then compressed which raises its temperature and it will then be passed on to a heat exchanging coil that is located within a hot water cylinder. The heated water in the cylinder is heated to 55 degrees and can then be used around the property. The system has a built in immersion which occasionally raises the temperature to 60 degrees to eliminate the risk of legionella.

A thermodynamic system can produce up to 100% of domestic heating needs. A system that uses thermodynamic panels will in theory be able to generate energy all year round due to it not being reliant on having optimal climate conditions to reach its maximum output potential. A thermodynamic panel can work in temperatures as low as -5 degrees Celsius although there are not as yet any official performance figures for systems operating in the UK. The main manufactures of thermodynamic systems are in Spain and Portugal and these systems were not designed for the UK initially. More companies are now developing more UK specific models and bringing them to market. As an example of performance, a four person family would need to utilise one panel and a 250 litre cylinder.

What's more, thermodynamic panels are also not currently approved by the Micro generation Certification Scheme, which means that they are not eligible for government green heat payments such as the Renewable Heat Incentive (RHI). This is sure to change however, and it is probable that thermodynamic panels will be eligible for the RHI in the future. The government says that it is currently gathering information on standards and performance.

Solar thermal air collectors

Solar air heaters are mostly used for space heating and can be both glazed and unglazed. They are among the **most efficient and economical** solar thermal technologies available and are mostly used in the commercial sector. The top sheet of a glazed system has a transparent top layer and an insulated surrounding frame and back panel to prevent heat loss to the surrounding air. An unglazed system uses an absorber plate which air passes over while heat is taken from the absorber.

Solar thermal bowl collectors

A **solar thermal bowl** is similar in fashion to a parabolic dish but has a fixed mirror instead of a tracking mirror which a parabolic dish would use. A tracking mirror is designed to track the sun's movement which is very costly on a large scale. A spherical or bowl mirror gets around the problem of tracking the sun in order to focus the light in one spot. A fixed mirror is at a disadvantage with regard to energy output as it cannot track the sun in order to focus the sunlight, however a fixed bowl will save the energy output that is associated with having to move a giant mirror to track the sun.

Domestic Solar Hot Water Systems

Low temperature solar thermal technologies, especially those that do not generate electricity, rely on the scientific principles behind the Greenhouse Effect to generate heat. Electromagnetic radiation from the sun, including visible and infrared wavelengths, penetrates into the collector that is absorbed by the surfaces inside the collector. Once the radiation is absorbed by the surfaces within the collector, the temperature rises. This increase in temperature can be used to heat water.

Domestic Solar Water Heating Systems

Solar Water Heating (SWH) is an effective method of utilising available energy sources to perform useful work. The energy from the sun can provide hot water for many domestic and industrial applications, displacing the need to burn fossil fuels. In Australia, around 25% of domestic energy consumption is devoted to the heating of water to low temperatures, of less than 100oC. Two main components of SWH systems are collectors and storage tanks. There are many different types of configurations and collectors. The most commonly used type of collector is the flat plate.

Flat Plate Collectors

These collectors consist of airtight boxes with a glass, or other transparent materia,l cover. There are several designs on the arrangement of the internal tubing of flat plate collectors as shown in Figure 1.

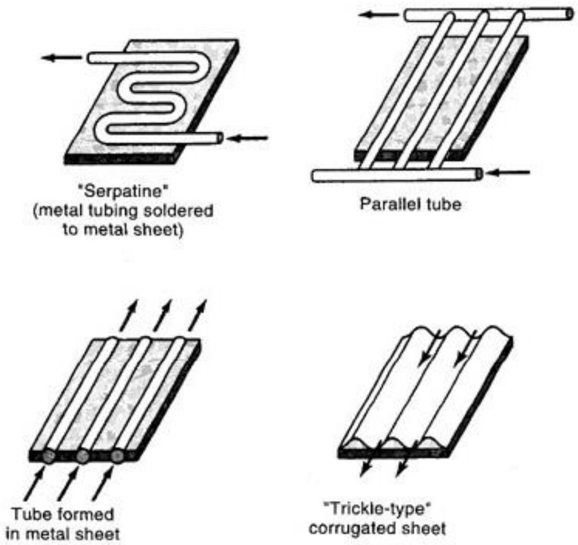


Figure 1 Internal tubing arrangement in flat plate collectors (copyright Saunders College Publishing)

Traditional collectors, like the Serpatine and Parallel tube examples above, consist of a number of copper tubes, known as risers that are orientated vertically with respect to the collector and placed in thermal contact with a black coloured, metal absorbing plate. The use of selective surfaces on absorbers improves the efficiency of solar water heaters significantly due to a very high absorbance (percentage of incoming energy that a material can absorb) and low emittance (percentage of energy that a material radiates away) of electromagnetic radiation. At the top and bottom of the metal absorbing plate, thicker copper pipes, known as headers, assist in the removal of heated water and the arrival of colder water to be heated. Insulation is placed between the absorbing plate and the external wall to prevent heat losses.

Whilst the principles of operation for flat plate collectors are fairly consistent, significant improvements in the design of systems, particularly absorber plates have occurred. Flooded plate collectors are similar to their tubed cousins, except that two metal absorbing plates are sandwiched together, allowing the water to flow through the whole plate. The increased thermal contact results in significant improvements in the efficiency of the system. In recent years, much research has been conducted on selective surfaces, which has seen significant improvements in the efficiency of solar water heaters. Today, a majority of absorber plates are composed of solar selective surfaces, made of materials that strongly absorb electromagnetic radiation (i.e. sunlight) but only weakly emit.

Batch Water Heaters

Batch water heaters, also known as ‘breadboxes’ are very simple passive systems for heating water using solar energy and have been used since the early 1900s. Batch systems consist of black storage tanks contained within an insulated box that has a transparent cover. Cold water is added to the hot water stored in the tanks whenever hot water is removed. Modern batch systems are used as preheating systems, where the water is then heated further by conventional gas, electric or wood systems. To retain the heat within the water, the system requires insulated covering to be placed over the glazing at night to prevent the heat being lost to the environment. Figure 2 shows a typical Breadbox water heater.

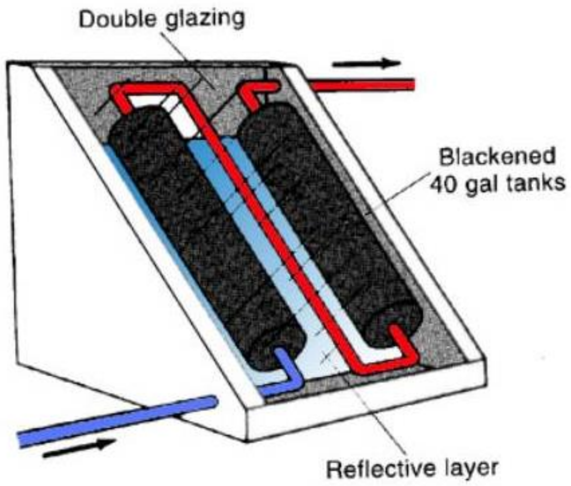


Figure 2 Breadbox water heater
(copyright Saunders College Publishing)

Selective Surfaces

According to Planck’s Law, the wavelength of radiation emitted from a surface is proportional to the temperature of the surface. Therefore, an ideal selective surface (the dark coloured material that lines the inside of the collector) for solar collectors should strongly absorb electromagnetic radiation (light) in the visible range and only weakly emit radiation back in the infrared range of the spectrum, so that the maximum amount of energy from the incoming sunlight is used to heat water. Several coating methods for selective surfaces are used in the manufacture of solar collector absorber plates:

- **Chemical**
- **Electroplated**
- **Vapour deposited**
- **Oxide**

Chemical coatings are usually sprayed onto the absorber plate metal, with or without the use of electricity. These coatings do not alter the re-radiative properties of the plate metal, only enhance the absorption of the solar radiation. The thickness of the chemical coating is proportional to the selectivity of the surface. That is, the coating thickness influences not only the absorptivity of the surface, but also the emissivity (how easily the surface emits the longer wavelength IR radiation).

Despite the low relative cost and ease of application, chemical coatings are often undesirable because of the temperatures reached inside collectors, which can cause a degradation in the chemical coatings. For example, black paint applied to the plate is considered to be a chemical coating. At high temperatures, the paint is likely to melt or burn off the surface, releasing volatile organic compounds into the environment.

Electroplated coatings are the most widely used coatings in the solar collector industry. These coatings are applied to the absorber plate metal using traditional electroplating technology. Prolonged exposure to elevated temperatures (around 200oC) and humidity can cause slow degradation in the selective coating as oxidation and crystal lattice reconstruction occurs. Black Chrome, a common electroplated coating used in the manufacture of solar collectors is relatively stable, particularly in humid, tropical conditions. Vapour deposited coatings are not traditionally used in flat plate collectors, as there are a number of significant engineering problems which are yet to be overcome. However, they are used extensively in evacuated collectors, which utilise a partial vacuum, such as the receivers in high temperature solar thermal systems.

Oxide coatings were the first type of coating used in solar collectors. Metals used in early solar collectors, such as copper and iron underwent natural oxidation, which have desirable absorptivity. However, as the oxidation processes occur naturally, they are difficult to control, which results in a change in the emissivity of the material and eventual degradation of the efficiency of the collector.

Evacuated tube solar thermal systems

The evacuated tube solar thermal system is one of the most popular solar thermal systems in operation. An evacuated solar system is the most efficient and a common means of solar thermal energy generation with a rate of efficiency of 70 per cent. As an example, if the collector generates 3000 kilowatt hours of energy in a year then 2100 kilowatt hours would be utilised in the system for heating water. The rate of efficiency is achieved because of the way in which the evacuated tube systems are constructed, meaning they have excellent insulation and are virtually unaffected by air temperatures. The collector itself is made up of rows of insulated glass tubes that contain copper pipes at their core. Water is heated in the collector and is then sent through the pipes to the water tank. This type of collector is the most efficient, but also the most expensive.

5. Explain solar energy applications in detail. **(Nov 2012) (Nov 2013)**

Solar Energy applications

i. Water heaters
ii. Air heaters
iii. Solar cooling
iv. Solar drying and power generation
v. Solar tower concept (solar plant)
vi. Solar pump

(i). SOLAR WATER HEATERS

Solar panels heat water that is delivered to a storage tank.| Photo courtesy of David Springer, National Renewable Energy Laboratory

Solar water heaters -- also called solar domestic hot water systems -- can be a cost-effective way to generate hot water for your home. They can be used in any climate, and the fuel they use -- sunshine -- is free.

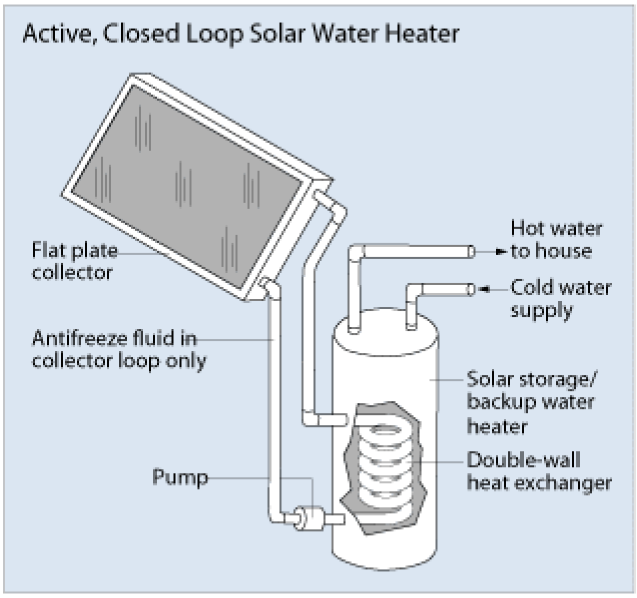
How They Work

Solar water heating systems include storage tanks and solar collectors. There are two types of solar water heating systems: active, which have circulating pumps and controls, and passive, which don't.

Active Solar Water Heating Systems

There are two types of active solar water heating systems:

- **Direct circulation systems**
  Pumps circulate household water through the collectors and into the home. They work well in climates where it rarely freezes.
- **Indirect circulation systems**
  Pumps circulate a non-freezing, heat-transfer fluid through the collectors and a heat exchanger. This heats the water that then flows into the home. They are popular in climates prone to freezing temperatures.

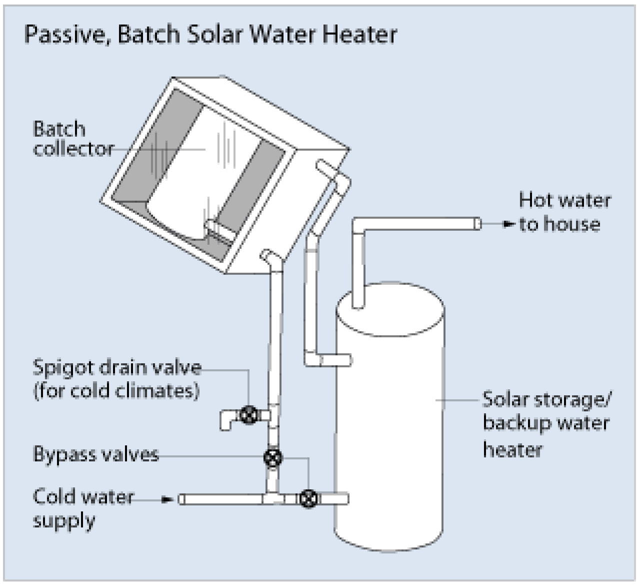


Passive Solar Water Heating Systems

Passive solar water heating systems are typically less expensive than active systems, but they're usually not as efficient. However, passive systems can be more reliable and may last longer. There are two basic types of passive systems:

- **Integral collector-storage passive systems**
  These work best in areas where temperatures rarely fall below freezing. They also work well in households with significant daytime and evening hot-water needs.

- **Thermosyphon systems**
  Water flows through the system when warm water rises as cooler water sinks. The collector must be installed below the storage tank so that warm water will rise into the tank. These systems are reliable, but contractors must pay careful attention to the roof design because of the heavy storage tank. They are usually more expensive than integral collector-storage passive systems.



Selecting a Solar Water Heater

Before you purchase and install a solar water heating system, you want to do the following:

- Estimate the cost and energy efficiency of a solar water heating system
- Evaluate your site's solar resource
- Determine the correct system size
- Investigate local codes, covenants, and regulations.

Also understand the various components needed for solar water heating systems, including the following:

- Heat exchangers for solar water heating systems
- Heat-transfer fluids for solar water heating systems

Improving Energy Efficiency

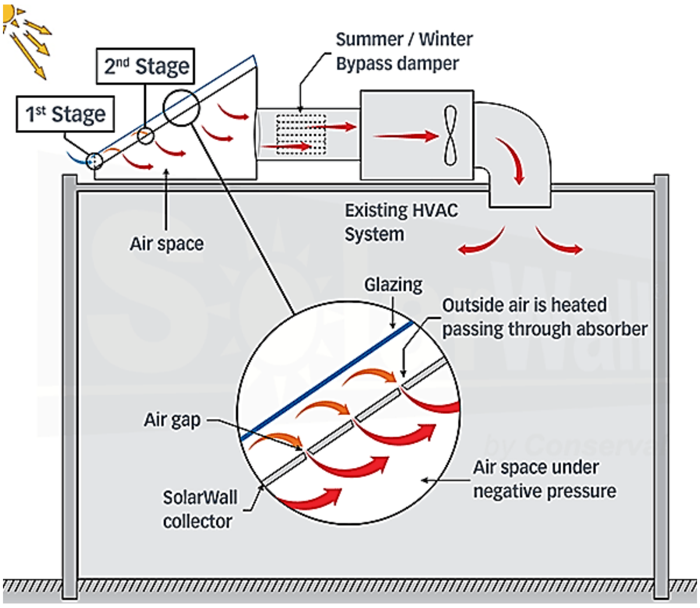
After your water heater is properly installed and maintained, try some additional energy-saving strategies to help lower your water heating bills, especially if you require a back-up system. Some energy-saving devices and systems are more cost-effective to install with the water heater.

(ii). SOLAR AIR HEATERS

Solar air heating is a solar thermal technology in which the energy from the sun, insolation, is captured by an absorbing medium and used to heat air. Solar air heating is a renewable energy heating technology used to heat or condition air for buildings or process heat applications. It is typically the most cost-effective out of all the solar technologies, especially in commercial and industrial applications, and it addresses the largest usage of building energy in heating climates, which is space heating and industrial process heating.

Solar air collectors can be divided into two categories:

- Unglazed Air Collectors or Transpired Solar Collector (used primarily to heat ambient air in commercial, industrial, agriculture and process applications)
- Glazed Solar Collectors (recirculating types that are usually used for space heating)



Solar air heaters are systems that collect solar energy and transfers the heat to passing air, which is either stored or used for space heating. The collectors are often black to absorb more of the sun's energy and a conductive material, often metal, acts as a heat exchanger. There are many different designs and systems may include fans to increase the flow rate of air. Alternatively, a passive collector can be built such that when the hot air rises it draws fresh air through the bottom. Fans can often increase the performance of the system, but require additional parts and adds complexity. Solar air heaters can compliment traditional indoor heating systems by providing a free and clean source of heat (after initial costs). While clouds effect the energy output of the system, the metal will store energy on a hot day and will reduce the impact of momentary cloud cover. To achieve best results, the system should be unshaded and facing the general direction of the sun.

Space heating applications

Space heating for residential and commercial applications can be done through the use of solar air heating panels. This configuration operates by drawing air from the building envelope or from the outdoor environment and passing it through the collector where the air warms via conduction from the absorber and is then supplied to the living or working space by either passive means or with the assistance of a fan. In the older days, before air conditioning, it would get hot inside buildings, during the day times, because of heat from the sun. Even in cars, the temperature inside can exceed 50 degrees Celsius, if the windows are up and there is no need to switch on the heater.

Process heat applications

Solar air heat can also be used in process applications such as drying laundry, crops (i.e. tea, corn, coffee) and other drying applications. Air heated through a solar collector and then passed over a medium to be dried can provide an efficient means by which to reduce the moisture content of the material.

Night cooling applications

Radiation cooling to the night sky is based on the principle of heat loss by long-wave radiation from a warm surface (roof) to another body at a lower temperature (sky). On a clear night, a typical sky-facing surface can cool at a rate of about 75 W/m2 (25 BTU/hr/ft2) This means that a metal roof facing the sky will be colder than the surrounding air temperature. Collectors can take advantage of this cooling phenomena. As warm night air touches the cooler surface of a transpired collector, heat is transferred to the metal, radiated to the sky and the cooled air is then drawn in through the perforated surface. Cool air may then be drawn into HVAC units.

Ventilation applications

By drawing air through a properly designed air collector or air heater, solar heated fresh air can reduce the heating load during sunny operation. Applications include transpired collectors preheating fresh air entering a heat recovery ventilator, or suction created by venting heated air out of some other solar chimney.

(iii). SOLAR COOLING

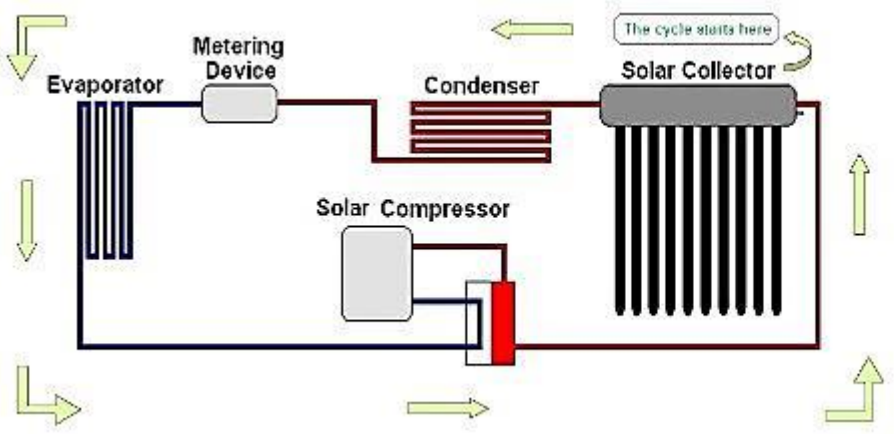
Solar energy can also be used to generate cool air. There are two kinds of solar cooling systems: desiccant systems and absorption chiller systems. In a desiccant system, air passes over a common desiccant or “drying material” such as silica gel to draw moisture from the air and make the air more comfortable. The desiccant is regenerated by using solar heat to dry it out. Absorption chiller systems, the most common solar cooling systems, use solar water heating collectors and a thermal-chemical absorption process to produce air-conditioning without using electricity. The process is nearly identical to that of a refrigerator, only no compressor is used. Instead, the absorption cycle is driven by a heated fluid from the solar collector.

Solar cooling systems use concentrating solar collectors and absorption chillers to drive the cooling process. These systems are ideal for cooling hotels, office buildings, data centers and other large commercial buildings.

Solar cooling systems save money for building owners because electricity rates are often tiered, meaning that the more electricity a building uses during peak hours, the higher the rate charged for that electricity. Peak hours often occur on hot sunny days when the air conditioning load is highest. Installing a solar cooling system can result in big savings since the system reduces electricity use during peak hours. What’s more, the same concentrating solar collectors used for cooling can also heat water for the facility.

How Does Solar Cooling Work?

Concentrating solar collectors use mirrors to focus the sun's energy on a tube containing fluid. The mirrors follow the sun, heating the fluid to very high temperatures. Absorption chillers operate by using this solar-heated fluid, rather than fossil fuels or electricity, to drive the refrigeration process. Using solar energy with absorption chillers reduces site-generated greenhouse gases as well as the emissions created when fossil fuels are burned to create electricity.



There are multiple alternatives to compressor-based chillers that can reduce energy consumption, with less noise and vibration. Solar thermal energy can be used to efficiently cool in the summer, and also heat domestic water and buildings in the winter. Single, double or triple iterative absorption cooling cycles are used in different solar thermal cooling system designs.

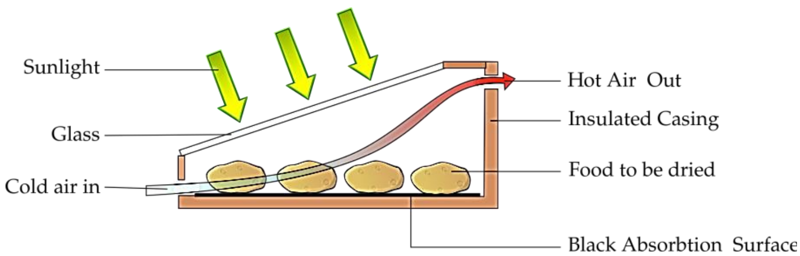
Solar cooling has a number of advantages over alternative solutions,

- It can help reduce the electricity peak demand associated with conventional cooling, as maximum solar radiation usually occurs when cooling is needed. Solar thermal cooling can also operate in the evening by using thermal storage.
- When summer is over, solar cooling systems can be used for heating purposes such as domestic hot water preparation or space heating.

(iv). SOLAR DRYING

Solar dryers are devices that use solar energy to dry substances, especially food. There are two general types of solar dryers: Direct and indirect.

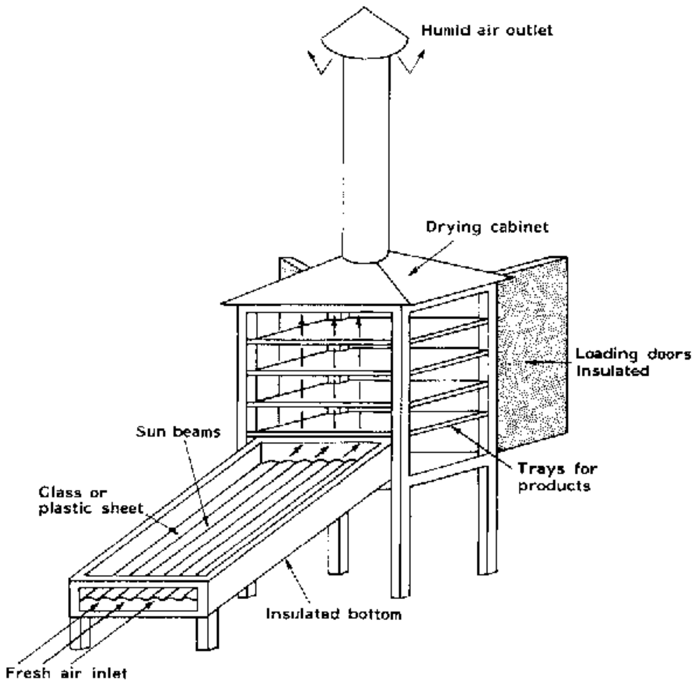
Direct



Direct solar dryers expose the substance to be dehydrated to direct sunlight. Historically, food and clothing was dried in the sun by using lines, or laying the items on rocks or on top of tents. In Mongolia cheese and meat are still traditionally dried using the top of the ger (tent) as a solar dryer. In these systems the solar drying is assisted by the movement of the air (wind) that removes the more saturated air away from the items being dried. More recently, complex drying racks and solar tents were constructed as solar dryers.

One modern type of solar dryer has a black absorbing surface which collects the light and converts it to heat; the substance to be dried is placed directly on this surface. These driers may have enclosures, glass covers and/or vents to in order to increase efficiency.

Indirect



Industrial indirect solar fruit and vegetable dryer

In indirect solar dryers, the black surface heats incoming air, rather than directly heating the substance to be dried. This heated air is then passed over the substance and exits upwards often through a chimney, taking moisture released from the substance with it. They can be very simple, just a tilted cold frame with black cloth to an insulated brick building with active ventilation and a back-up heating system. One of the advantages of the indirect system is that it is easier to protect the food, or other substance, from contamination whether wind-blown or by birds, insects, or animals. Also, direct sun can chemically alter some foods making them less appetizing.

(v). SOLAR TOWER CONCEPT (SOLAR PLANT)

The Solar Power Tower is another concept for generating electricity by using the solar energy in the form of heat. This technology has seen and presently going through developments. Tower Power technology is less mature as compared to the technology of electricity generation using parabolic trough collector or sterling dish collectors. They are even known by the name Solar Updraft Tower. Power Towers have been implemented the world over on an experimental basis since the past two decades. The basic purpose of the implementation was to demonstrate the feasibility of application and economic usefulness of the power tower technology.

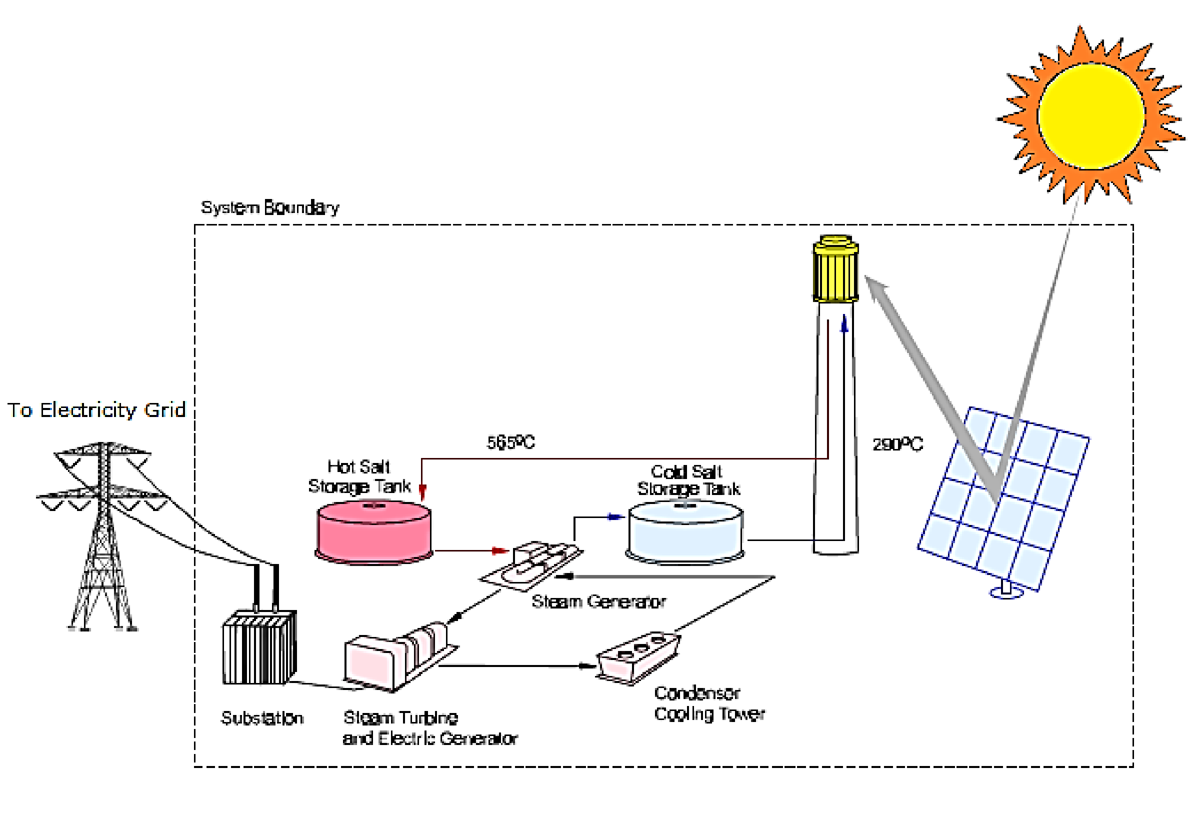
System Description

A Solar Power Tower generates electricity by using the solar energy in the form of heat. A large number of heliostats are used to generate heat from sunlight. The Heliostats concentrate incident light on a tower mounted Receiver.

Molten salt is stored in a "cold storage tank" in a molten salt based solar power tower. The temperature of the salt in the liquid state is around 290°C to 300°C. This molten salt mass is pumped to the overhead receiver where it gets heated to a temperature of around 550°C to 565°C. Upon heating it is transferred to a "hot tank". Where it is either stored for further use during the day or is used for power generation during peak loads.

Now when power is required the salt in liquid form is pumped to a system which generates superheated steam. This superheated steam then acts as the prime mover to a "Rankine Cycle" Turbine coupled to a generator system.Thus generating solar electricity.

The molten salt is taken back to the "cold" storage tank, which can be transferred to the receiver for reheating and the process keeps on repeating.



Solar Power Tower System

The number of heliostats and the area of the heliostatic field depends on the requirement of the generating station. That means higher the Mega watt power generated larger the heliostat area. For any particular tower power system, the harvesting of solar energy takes place much more than the steam required for powering the turbine.

Thus the storage system can continue to work even when the system is busy generating electricity using the superheated steam.

The ratio of thermal capacity of the heliostatic field to the peak thermal power required by the turbine is termed as solar multiple.

The higher the solar multiple ensures that the plant continues to generate electricity even after sunset or during cloudy days.

(vi). SOLAR PUMP

Getting grid power to a location where you need a pump is often not cost effective or practical. Whether you have a dam down the hill, a bore in the field, or a tank at the end of your property, in most cases you cannot choose the location of your pump. You can, however, choose the power source.

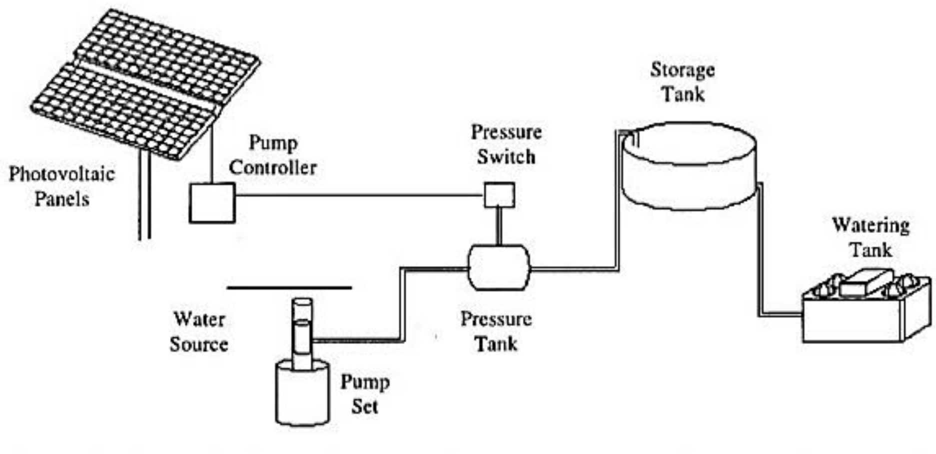


Fig 4. Block Diagram of SDPS

- In solar direct pumping system electricity from the PV modules is sent directly to the pump which in turn pumps water through a pipe to where its needed.
- Solar direct pumping systems are sized to store extra water on sunny days so it is available on cloudy days and at night. Water can be stored in a larger than needed watering tank or in a separate storage tank and then gravity fed to smaller watering tanks.

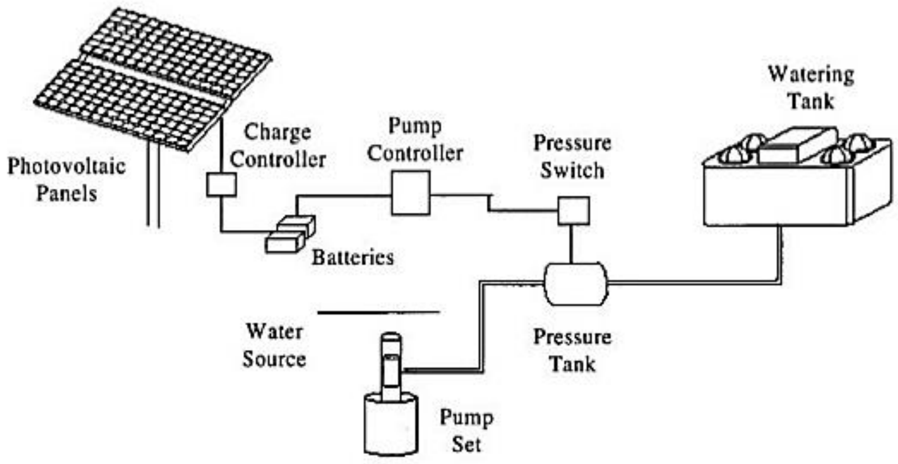


Fig 5. Block diagram of BSPS

- Cost is a factor that must be considered when selecting a solar powered system.
- Total cost depends on many factors such as the type of system (Solar-direct, battery based) daily water requirements, complexity of the water delivery system etc.
- For example low volume solar pumping system keep costs down when compared to higher output solar pumping system by using a minimum number of solar panels and by using the entire daylight period to charge batteries or pump water.

Pumping with renewable energy was first recorded in the 9th century - using wind as the power source. Windpumps or windmills have since turned into an iconic structure in many countries, including Australia. Although those windpumps are still part of our rural landscape they have been superseded by **solar pump systems** which are more efficient, quieter, and require a lot less maintenance.

Solar Energy as Power Source

Solar energy as a power source for water pumping is an ideal solution where water is required when the sun is shining, or where it can be stored in a high location (eg in a header tank). Solar pump systems can also be configured as 'hybrid' systems and incorporate an additional power source, eg a generator.

Solar Pump Systems for Home Use

First off, a solar pump system can usually NOT replace a home pressure pump. Water may not be needed around the clock but certainly after dark or before sunlight. Hence we only recommend a solar pump system for your home if you have

- a sizeable header tank
- a bore hole (min 100mm ø) with clean (tested) water
- not more than 50 metres between bottom of bore and top of tank.

Since water can only be pumped during sun-shine hours you need a header tank that is at least a few meters higher than your house. The pressure in your pipes is then supplied by gravity - simple, reliable and renewable.

Advantages

- Low operating cost
- Free fuel
- Environmental friendly
- Easy transportation

Disadvantages

- Variable yield
- Water quality
- Theft

Applications

- Agriculture livestock watering / crop irrigation, home gardens and drip irrigation systems.
- Domestic portable water for remote homes, campgrounds.
- Pond water management and water transfer.
- Water supply for villages in developing world.

PONDICHERRY UNIVERSITY QUESTIONS

2 MARKS

1. Define solar constant? **(April 2015) (Nov 2013)**
2. Draw the VI characteristics of Solar PV cell. **(April/May 2012)**
3. What is solar collector? **(April 2013)**
4. List the advantages of solar Energy. **(Nov 2013)**
5. Name few applications of solar energy. **(Nov 2012)**
6. What are the components of solar energy? **(April 2014)**
7. Define solar energy. **(November 2011)**
8. Define solar constant in solar energy. **(November 2012)**
9. List any four applications of solar collectors. **(November 2012)**
10. What are the applications of solar water heater? **(November 2012)**
11. What are the applications of solar air heaters? **(Nov 2012)**
12. Define PV effect. **(April 2012)**
13. Define solar altitude angle. **(April 2012)**
14. What are the two basic types of instruments employed for solar radiation measurements. **(Nov 2013)**
15. Define collector efficiency. **(Nov 2012)**

11 MARKS

1. Explain the block diagram and working of solar power generation. Draw the schematic diagram of a solar PV plant and explain. Describe construction and working of solar cell. **(April 2013)(April/May 2012)(Nov 2012)(April/May 2014)**
2. Explain about VI characteristics of a solar cell. **(Nov/Dec 2014)**
3. Explain solar energy applications in detail. **(Nov 2012) (Nov 2013)**
4. Explain the different types of solar collectors and its efficiencies. **(Nov 2012) (Nov 2013)**

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ASPIRE TO EXCEL

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

Subject Name: **Renewable Energy Sources** Subject Code: **EEE 12**

UNIT III: WIND ENERGY

Energy from the wind- General theory of wind mills- Types of wind mills-performance of wind machines-wind power-efficiency. Merits and Limitations of Wind energy system-Modes of wind power generation.

2- MARKS

1. What is the principle of wind power generation?

Principle of wind energy generation is to convert kinetic energy of moving air (wind) into electrical energy. If mechanical energy is directly used it is called a windmill. e.g. Pump. If mechanical energy is used to generate electrical energy and then used it is a wind energy converter and clusters of wind mills are called a wind form.

2. What are the main components of WECS?

1. Rotor
2. Gearbox
3. Enclosure
4. Generator

3. What are the two basic designs of turbines?

1. Vertical axis (or) Egg beater style
2. Horizontal axis (propeller style) machines

4. Write down the various types of wind power plants.

1. Remote
2. Hybrid
3. Grid connected

5. How are wind turbine are classified? (April/May 2012)

According the axis of rotation

1. Vertical axis wind turbine
2. Horizontal axis wind turbine

According the range of output power

1. Small scale
2. Medium scale
3. Large scale

According to the no of generator used

1. Single generator system
2. Multiple generator system

According to the types of output power

1. AC and DC

6. What are the disadvantages of wind power generation system? **(Nov 2013)**

1. Low energy production
2. Expensive maintenance
3. Noise Disturbances
4. Wind can never be predicted
5. Threat to wild life.

7. List any four advantages of wind turbine.

1. Inexhaustible fuel source
2. No pollution
3. Excellent supplement to other renewable source
4. Its free

8. Write wind power equation.

$P = \frac{1}{2}\rho A V_{\propto}^{3} \frac{16}{17}$is the power extraction of wind.

Where

ρ – Air Density

A- Swept area

$V_{\propto}$- Wind sped/ velocity

9. What is the type of generator used in wind power plant?

1. Asynchronous (induction) Generator
   a) Squirrel Cage induction Generator (SCIG)
   b) Wound Rotor induction Generator (WRIG)
   1. Slip ring induction generator
   2. Doubly-Fed induction generator(DFIG)
2. Synchronous Generator
   a) Wound rotor Generator (WRSG)
   b) Permanent Magnet Generator(PMSG)
3. Other Types of Potential Interest
   a) High-Voltage Generator(HVG)
   b) Switch Reluctance Generator(SRG)
   c) Transverse Flux Generator(TFG)

10. Define Tip speed ratio.

The Tip Speed Ratio (TSR) is an extremely important factor in wind turbine design. TSR refers to the ratio between the wind speed and the speed of the tips of the wind turbine blades. TSR (λ) = If the rotor of the wind turbine spins too.

11. What are wind farms?

Converts kinetic energy in moving air (wind) into electrical energy. If mechanical energy is directly used it is called a wind mill. 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.

12. What is meant by pitch angle? (April/May 2016)

The pitch angle is the angle at which the blade surface contacts the wind. It is often variable to ensure optimum operation of the turbine in varying wind conditions and to prevent electrical overload and over speed in high winds. Gears in the hub of the rotor allow the pitch to be varied.

13. What are the applications of wind machines?

Wind machines are typically used for mechanical applications like water pumping, grinding, woodcutting, or for AC or DC power generation in grid connected or isolated mode.

14. What is Power coefficient?(Nov 2012)

Coefficient of Performance, CP = P / (½ ρ AS u3)

Where,

P = Power output at rotor shaft (W)

AS = Area swept by the machine (m2)

ρ = Air density (kg/m3)

u = Undisturbed wind speed (m/s)

15. What are the characteristics of wind energy?

Wind is an indirect solar energy source. Its characteristics can be summarized as follows.

- It is environmentally clean source of energy.
- It is a dilute source of energy.
  It is perennially available.
- Its availability is unpredictable.
- Data are available about its availability pattern around the day for different months of the year.

16. List out the factor led to accelerated development of wind power.

- Availability of high strength fibre composites for constructing large low cost rotor blades
- Falling prices of power electronics
- Variable speed operation of electrical generators to capture maximum energy
- Improved plant operation, pushing the availability upto 95%.
- Economy of scale, as the turbines and plants are getting largerin size.
- Accumulated field experience improving the capacity factor
- Short energy payback period of about one year

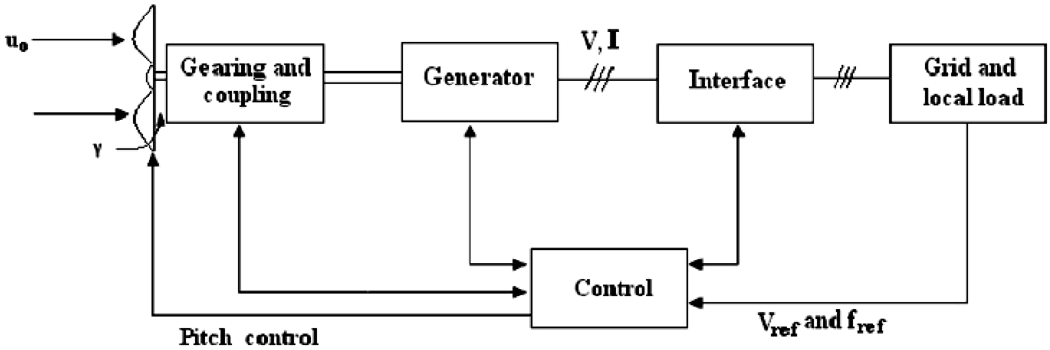
17. What are the merits and demerits of three blade rotor over two blade rotors?

Compared to the two blade design, the three blade machine has smoother power output and balanced gyroscopic force.

- There is no need to teeter the rotor, allowing the use of a simple rigid hub. The blades may be cross-linked for greater rigidity.

- ❖ Adding a third blade increases the power output by about 5%only, while the weight and cost of a rotor increases by 50%, thus giving a diminished rate of return for additional 50%weight and cost.
- ❖ The two blade rotor is also simpler to erect, since it can be assembled on the ground and lifted to the shaft without complicated maneuvers during the lift.

18. Draw the block diagram of WECS.



19. Define gusts

Rapid fluctuations in the wind velocity over a wide range of frequencies and amplitudes, due to turbulence caused by mechanical mixing of lower layers of atmosphere by surface roughness, are commonly known as gusts

20. What are the features of VAWT?

The features of VAWT:

1. It can accept wind from any direction, eliminating the need of yaw control.
2. The gearbox, generator, etc., are located at the ground, thus eliminating the heavy nacelle at the top of the tower, thus simplifying the design and installation of the whole structure, including the tower.
3. The inspection and maintenance also gets easier
4. It also reduces the overall cost

21. Classify the schemes available for electric generation.

The schemes are available for electric generation is of three categories.

1. Constant-speed constant frequency systems(CSCF)
2. Variable speed constant frequency systems(VSCF)
3. Variable speed variable frequency systems(VSVF

22. What is cut in speed and cutout wind speeds for turbine?

CUT IN SPEED

Wind speed at which wind turbine starts delivering shaft power.

Cut in speed:

While operating - 7m/s

While stopping - 5m/s

CUT OUT SPEED

At high velocities during storms, it is necessary to cut out the power conversion of wind turbine by furling the wind turbine blades. The speed at which power conversion is cut out is called cut out wind speed or furling winds peed.

Cut out speed:

While operating - 20m/s

While stopping - 17m/s

Rated speed - 14m/s

23. Name the two natural phenomena in the atmosphere of different origins.

Winds are natural phenomena in the atmosphere and have two different origins.

Planetary Winds

Planetary winds are caused by daily rotation of earth around its polar axis and unequal temperatures between polar regions and equatorial region.

Local Winds

Local winds are caused by unequal heating and cooling of ground surfaces and ocean/lake surfaces during day and night

24. Name the characteristics in which the speed of a wind turbine rotor depends.

The speed of a wind turbine rotor depends principally on

- Wind speed
- Pitch of the turbine blades
- Mechanical and electrical load i.e., shaft load, friction, breaking force etc.,

25. Mention the advantages of vertical axis wind turbine over horizontal axis

- They will react to wind from any direction and therefore do not need yawing equipment to turn the rotor into the wind.
- They can require less structural support because heavy components can be located at ground level.
- This configuration also eases installation and maintenance.
- Since the blades do not turn end over end, the rotor is not subjected to continue cyclic gravity loads.

26. What are the types of rotors for HAWT?(Nov 2012)

The different types of rotor for HAWT are:

- Single blade rotor
- Two blade rotor
- Three blade rotor
- Sailing rotor
- Chalk multi blade rotor
- American multi bladed rotor
- Dutch type rotor

27. What are the types of rotors for VAWT?

The different types of rotor for HAWT are:

- Cup type rotor
- Savonious rotor
- Darrieus rotor
- Musgrove rotor
- Evans rotor

28. What are the characteristics of good wind power site?

- A site should have a high annual wind speed
- There should not be any obstructions for a radius of 3Km
- An open plain or an open line may be a good location

29. What are the features of lift and drag?

- Drag in the direction of air flow

- Lift perpendicular to the direction of air flow
- Generation of lift always causes certain amount of drag to be developed
- Lift devices are more efficient than drag devices

30. List the various factors to be consider for the site selection of wind turbine (Nov 2013)

a. Technical Considerations.
b. Wind Speed
c. Land topography and geology
d. Grid structure and distance.
e. Turbine size
f. Capital cost
g. Land cost
h. Operational and management cost
i. Electricity market
j. Environmental Considerations
k. Visual impact
l. Wild life & endangered species.
m. Electromagnetic interference.
n. Noise impact
o. Social Considerations.
p. Regulatory boundaries
q. Public acceptance
r. Land use
s. Distance from the residential area.

11 Marks

1. Explain about the wind energy types in detail.

Wind turbines are classified into two general types: Horizontal axis and Vertical axis. A horizontal axis machine has its blades rotating on an axis parallel to the ground. A vertical axis machine has its blades rotating on an axis perpendicular to the ground. There are a number of available designs for both and each type has certain advantages and disadvantages. However, compared with the horizontal axis type, very few vertical axis machines are available commercially.

Horizontal Axis Wind Turbine (HAWT):

HAWTs have emerged as the most successful type of turbines. These are being used for commercial energy generation in many parts of the world. Their theoretical basis is well researched and sufficient field experience is available with them.

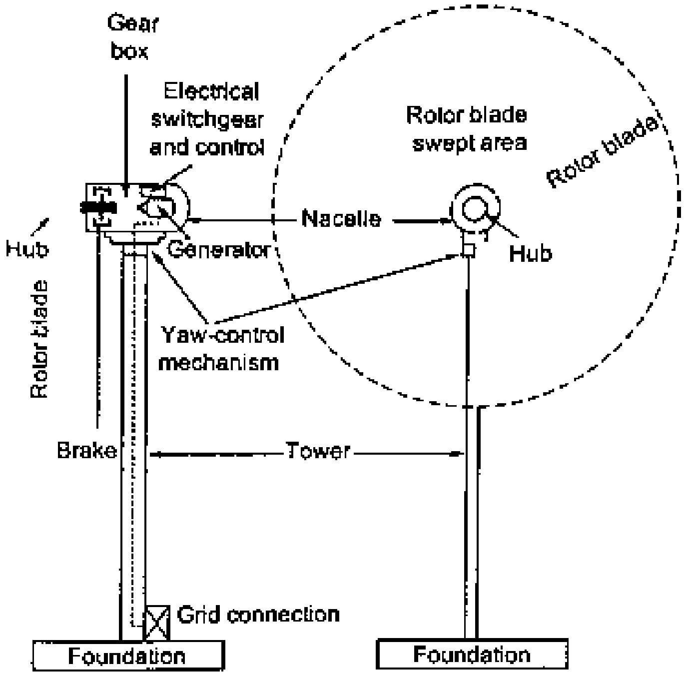


Fig. 7.14 *Horizontal axis wind turbine*

Main Components:

The constructional details of the most common, three-blade rotor, horizontal axis wind turbine is shown in figure. The main parts are as follows:

Turbine Blades: Turbine blades are made of high-density wood or glass fibre and epoxy composites. They have an airfoil type of cross section. The blades are slightly twisted from the outer tip to the root to reduce the tendency to stall. In addition to centrifugal force and fatigue due to continuous vibrations, there are many extraneous forces arising from wind turbulence, gust, gravitational forces and directional changes in the wind. All these factors are to be taken care off at the designing stage. The diameter is typical, MW range, modern rotor may be of the order of 100m.

Modern wind turbines have two or three blades. Two/three blade rotor HAWT are also known as *propeller-type* wind turbines owing to their similarity with propellers of old aeroplanes.

However, the rotor rpm in case of wind turbine is very low as compared to that for propellers. The relative merits and demerits of two-blades and three-blade rotors are as follows:

- Compared to the two-blade design, the three-blade machine has smoother power output and balanced gyroscopic force.
- There is no need to teeter (to be discussed later in this section) the rotor, allowing the use of a simple rigid hub. The blades may be cross-linked for greater rigidity.
- Adding a third blade increases the power output by about 5% only, while the weight and cost of a rotor increases by 50%, thus giving a diminished rate of return for additional 50% weight and cost.
- The two-blade rotor is also simpler to erect, since it can be assembled on the ground and lifted to the shaft without complicated maneuvers during the lift.

HUB:

The central solid portion of the rotor wheel is known as hub. All blades are attached to the hub. The mechanism for pitch angle control is also provided inside the hub.

NACELLE:

The term nacelle is derived from the name for housing containing the engines of an aircraft. The rotor is attached to the nacelle, and mounted at the top of a tower. It contains rotor brakes, gearbox, generator and electrical switchgear and control. Brakes are used to stop the rotor when power generation is not desired. The gearbox steps up the shaft rpm to suit the generator. Protection and control functions are provided by switchgear and control block. The generated electrical power is conducted to ground terminals through a cable.

YAW-CONTROL MECHANISM:

The mechanism to adjust the nacelle around the vertical axis to keep it facing the wind is provided at the base of the nacelle.

TOWER:

The tower supports the nacelle and rotor. For medium and large sized turbines, the tower is slightly taller than the rotor diameter. In case of a small-sized turbine, the tower is much larger than the rotor diameter as the air is erratic at lower heights. Both steel and concrete towers are being used. The construction can be either tubular or lattice type.

The tower vibrations and resulting fatigue cycles under wind speed fluctuations are avoided by careful design. This requires avoidance of all resonance frequencies of tower, the rotor and the nacelle from the wind-fluctuation frequencies.

(ii) Vertical axis:

Although vertical axis wind turbines have existed for centuries, they are not as common as their horizontal counterparts. The main reason for this is that they do not take advantage of the higher wind speeds at higher elevations above the ground as well as horizontal axis turbines. The basic vertical axis designs are the Darrieus, which has curved blades and efficiency of 35%, the Giromill, which has straight blades, and efficiency of 35%, and the Savonius, which uses scoops to catch the wind and the efficiency of 30%. A vertical axis machine need not be oriented with respect to wind direction. Because the shaft is vertical, the transmission and generator can be mounted at ground level allowing easier servicing and a lighter weight, lower cost tower. Although vertical axis wind turbines have these advantages, their designs are not as efficient at collecting energy from the wind as are the horizontal machine designs.

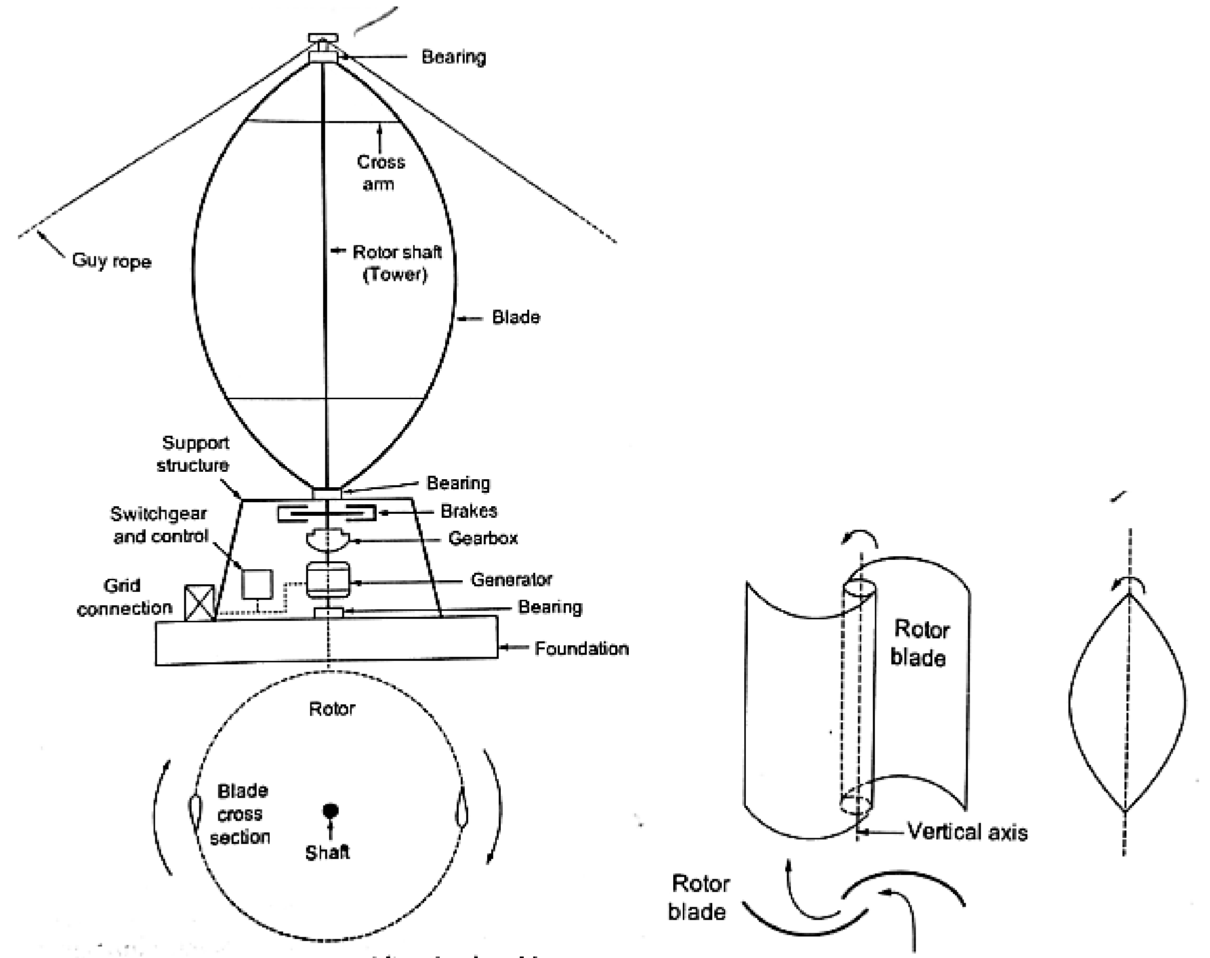


Fig. 7.19 *Vertical axis wind (Darrieus) turbine* (b) Savonious rotor (c) Darrieus rotor

There is one more type of wind-mill called Cyclo-gyro wind-mill with very high efficiency of about 60%. However, it is not very stable and is very sensitive to wind direction. It is also very complex to build.

VAWTs are in the development stage and many models are undergoing field trial. The main attractions of a VAWT are:

i. It can accept wind from any direction, eliminating the need of yaw control.
ii. The gearbox, generator, etc., are locate at the ground, thus eliminating th4e heavy nacelle at the top of the tower, thus simplifying the design and installation of the whole structure, including the tower.
iii. The inspection and maintenance also gets easier, and
iv. It also reduces the overall cost.

Main components:

The constructional details of a vertical axis wind turbine (Darrieus-type rotor) are shown in figure. The details of the main components are as follows:

Tower (or rotor shaft):

The tower is a hollow vertical rotor shaft, which rotated freely about the vertical axis between the top and bottom bearings. It is installed above a support structure. In the absence of any load at the top, a very strong tower is not required, which greatly simplifies its design. The upper part of the tower is supported by guy ropes. The height of the tower of a large turbine is around 100m.

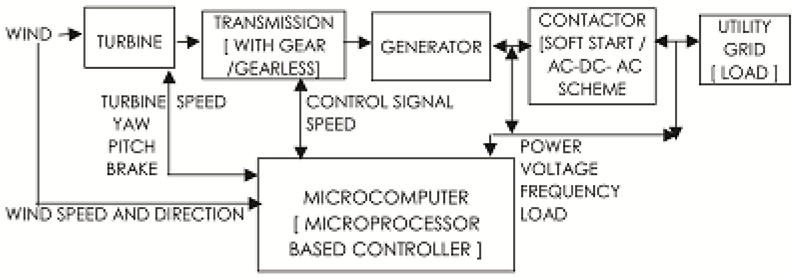
Blades:

It has two or three thin, curved blades like an eggbeater in a profile, with blades curved in a form that minimizes the bending stress caused by centrifugal forces—the so called "Troposkien" profile. The blades have an airfoil cross section with constant chord length. The pitch of the blades cannot be changed. The diameter of the rotor is slightly less than the tower height. The first large (3.8 MW), Darrieus type, Canadian machine has a rotor height as 94m and the diameter as 65m with a chord of 2.4m.

Support Structure:

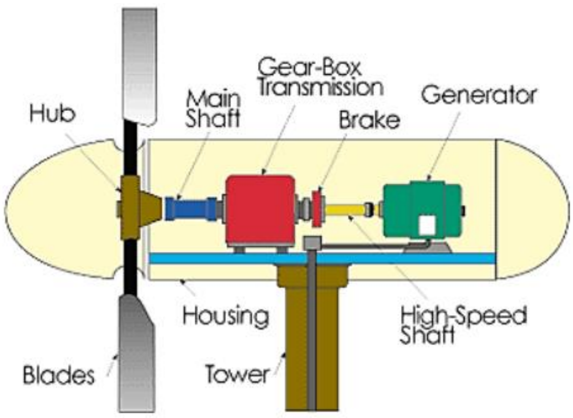
The support structure is provided at the ground to support the weight of the rotor. Gearbox, generator, brakes, electrical switchgear and controls are housed within this structure.

2. With neat sketch explain the function of wind power generation system. (April/May 2012)



Main components of a wind-mill:

Fig. below shows typical components of a horizontal axis wind mill.



Rotor:

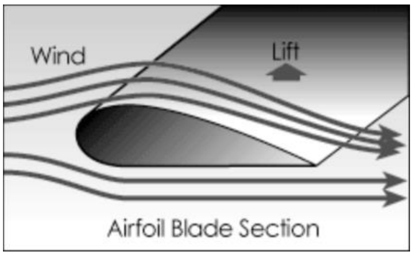
The portion of the wind turbine that collects energy from the wind is called the rotor. The rotor usually consists of two or more wooden, fiberglass or metal blades which rotate about an axis (horizontal or vertical) at a rate determined by the wind speed and the shape of the blades. The blades are attached to the hub, which in turn is attached to the main shaft.

Drag design:

Blade designs operate on either the principle of drag or lift. For the drag design, the wind literally pushes the blades out of the way. Drag powered wind turbines are characterized by slower rotational speeds and high torque capabilities. They are useful for the pumping, sawing or grinding work. For example, a farm-type windmill must develop high torque at start-up in order to pump, or lift, water from a deep well.

Lift design:

The lift blade design employs the same principle that enables airplanes, kites and birds to fly. The blade is essentially an airfoil, or wing. When air flows past the blade, a wind speed and pressure differential is created between the upper and lower blade surfaces. The pressure at the lower surface is greater and thus acts to "lift" the blade. When blades are attached to a central axis, like a wind turbine rotor, the lift is translated into rotational motion. Lift-powered wind turbines have much higher rotational speeds than drag types and therefore well suited for electricity generation.
Fig. below gives an idea about the drag and lift principle.



Tip Speed Ratio:

The tip-speed is the ratio of the rotational speed of the blade to the wind speed. The larger this ratio, the faster the rotation of the wind turbine rotor at a given wind speed. Electricity generation requires high rotational speeds. Lift-type wind turbines have maximum tip-speed ratios of around 10, while drag-type ratios are approximately 1. Given the high rotational speed requirements of electrical generators, it is clear that the lift-type wind turbine is most practical for this application.

The number of blades that make up a rotor and the total area they cover affect wind turbine performance. For a lift-type rotor to function effectively, the wind must flow smoothly over the blades. To avoid turbulence, spacing between blades should be great enough so that one blade will not encounter the disturbed, weaker air flow caused by the blade which passed before it. It is because of this requirement that most wind turbines have only two or three blades on their rotors.

Generator:

The generator is what converts the turning motion of a wind turbine's blades into electricity. Inside this component, coils of wire are rotated in a magnetic field to produce electricity. Different generator designs produce either alternating current (AC) or direct current (DC), and they are available in a large range of output power ratings. The generator's rating, or size, is dependent on the length of the wind turbine's blades because more energy is captured by longer blades.

It is important to select the right type of generator to match intended use. Most home and office appliances operate on 240 volt, 50 cycles AC. Some appliances can operate on either AC or DC, such as light bulbs and resistance heaters, and many others can be adapted to run on DC. Storage systems using batteries store DC and usually are configured at voltages of between 12 volts and 120 volts. Generators that produce AC are generally equipped with features to produce the correct voltage of 240 V and constant frequency 50 cycles of electricity, even when the wind speed is fluctuating.

DC generators are normally used in battery charging applications and for operating DC appliances and machinery. They also can be used to produce AC electricity with the use of an inverter, which converts DC to AC.

Transmission:

The number of revolutions per minute (rpm) of a wind turbine rotor can range between 40 rpm and 400 rpm, depending on the model and the wind speed. Generators typically require rpm's of 1,200 to 1,800. As a result, most wind turbines require a gear-box transmission to increase the rotation of the generator to the speeds necessary for efficient electricity production. Some DC-type wind turbines do not use transmissions. Instead, they have a direct link between the rotor and generator. These are known as direct drive systems. Without a transmission, wind turbine complexity and maintenance requirements are reduced, but a much larger generator is required to deliver the same power output as the AC-type wind turbines.

Tower:

The tower on which a wind turbine is mounted is not just a support structure. It also raises the wind turbine so that its blades safely clear the ground and so it can reach the stronger winds at higher elevations. Maximum tower height is optional in most cases, except where zoning restrictions apply. The decision of what height tower to use will be based on the cost of taller towers versus the value of the increase in energy production resulting from their use. Studies have shown that the added cost of increasing tower height is often justified by the added power generated from the stronger winds. Larger wind turbines are usually mounted on towers ranging from 40 to 70 meters tall.

Towers for small wind systems are generally "guyed" designs. This means that there are guy wires anchored to the ground on three or four sides of the tower to hold it erect. These towers cost less than freestanding towers, but require more land area to anchor the guy wires. Some of these guyed towers are erected by tilting them up. This operation can be quickly accomplished using only a winch, with the turbine already mounted to the tower top. This simplifies not only installation, but maintenance as well. Towers can be constructed of a simple tube, a wooden pole or a lattice of tubes, rods, and angle iron. Large wind turbines may be mounted on lattice towers, tube towers or guyed tilt-up towers.

Towers must be strong enough to support the wind turbine and to sustain vibration, wind loading and the overall weather elements for the lifetime of the wind turbine. Their costs will vary widely as a function of design and height.

3. Explain about the operating characteristics of wind mills?(Nov 2013)

All wind machines share certain operating characteristics, such as cut-in, rated and cut-out wind speeds.

Cut-in speed:

Cut-in speed is the minimum wind speed at which the blades will turn and generate usable power. This wind speed is typically between 10 and 16 kmph.

Rated speed:

The rated speed is the minimum wind speed at which the wind turbine will generate its designated rated power. For example, a "10 kilowatt" wind turbine may not generate 10 kilowatts until wind speeds reach 40 kmph. Rated speed for most machines is in the range of 40 to 55 kmph. At wind speeds between cut-in and rated, the power output from a wind turbine increases as the wind increases. The output of most machines levels off above the rated speed. Most manufacturers provide graphs, called "power curves," showing how their wind turbine output varies with wind speed.

Cut-out speed:

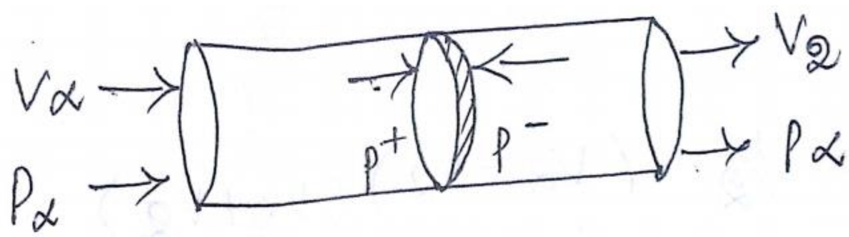
At very high wind speeds, typically between 72 and 128 kmph, most wind turbines cease power generation and shut down. The wind speed at which shut down occurs is called the cut-out speed. Having a cut-out speed is a safety feature which protects the wind turbine from damage. Shut down may occur in one of several ways. In some machines an automatic brake is activated by a wind speed sensor. Some machines twistor "pitch" the blades to spill the wind. Still others use "spoilers," drag flaps mounted on the blades or the hub which are automatically activated by high rotor rpm's, or mechanically activated by a spring loaded device which turns the machine sideways to the wind stream. Normal wind turbine operation usually resumes when the wind drops back to a safe level.

Betz limit:

It is the flow of air over the blades and through the rotor area that makes a wind turbine function. The wind turbine extracts energy by slowing the wind down. The theoretical maximum amount of energy in the wind that can be collected by a wind turbine's rotor is approximately 59%. This value is known as the Betz limit. If the blades were 100% efficient, a wind turbine would not work because the air, having given up all its energy, would entirely stop. In practice, the collection efficiency of a rotor is not as high as 59%. A more typical efficiency is 35% to 45%. A complete wind energy system, including rotor, transmission, generator, storage and other devices, which all have less than perfect efficiencies, will deliver between 10% and 30% of the original energy available in the wind.

4. Derive the mathematical expression governing wind power?

The wind power is generated due to the movement of wind. The energy associated with such movement is the kinetic energy and is given by the following expression:



According to Bernoulli's principle

Energy per unit volume before = Energy per unit volume after

Power extraction = Loss in kinetic energy

Energy per unit volume before = Energy per unit volume after.

$\frac{1}{2}\,\rho V\alpha^2 + P\alpha = \frac{1}{2}\,\rho u^2 + P^+$…..(1)

$\frac{1}{2}\rho V_2^2 + P\alpha = \frac{1}{2}\rho u^2 + P^-$……(2)

From eqn 1 and eqn 2,

$\frac{1}{2}\rho(V\alpha^2 - V_2^2) = P^+ - P^-$……(3)

This equation is pressure difference.

Thrust (Force) = $(P^+ - P^-)$ A ……(4)

Thrust = $\frac{1}{2}\rho(V\alpha^2 - V_2^2)$ A …….(5)

Thrust F= mA

F= M $(V_\alpha - V_2)$ ………..(6)

$\frac{1}{2}\rho(V\alpha^2 - V_2^2) = M(V_\alpha - V_2)$ ………….(7)

$$\frac{1}{2}\rho(V\alpha^2 - V_2^2) = \rho Av(V_\alpha - V_2)$$

$$\frac{1}{2}\left(\frac{V\alpha^2 - V_2^2}{(V_\alpha - V_2)}\right) = v$$

$$v = \frac{1}{2}\left(\frac{(V_\alpha - V_2)(V_\alpha - V_2)}{(V_\alpha - V_2)}\right)$$

$v = \frac{1}{2}(V_\alpha + V_2)$ ……….(8)

$v = V_\alpha(1 - a)$ ……….(9)

a=0

$v = V_\alpha$

$v = V_\alpha(1 - a)$

a=1

v=0

Equate eqn 8 and eqn 9

$$v = \frac{1}{2}(V_\alpha + V_2) = V_\alpha(1 - a)$$

$(V_\alpha + V_2) = 2V_\alpha(1 - a)$

$(V_\alpha + V_2) = 2V_\alpha - 2V_\alpha a)$

$V_2 = V_\alpha - 2V_\alpha a$

$V_2 = V_\alpha(1 - 2a)$

$$P = \frac{1}{2}\rho Av(V\alpha^2 - V_2^2)$$

Sub $v = V_\alpha(1 - a)$

$V_2 = V_\alpha(1 - 2a)$

$$P = \frac{1}{2}\ \rho A V_\alpha (1-a)(V_\propto^2 - \ (V_\alpha (1-2a))^2$$

$$P = \frac{1}{2}\ \rho A V_\alpha (1-a)(V_\propto^2 - \ (V_\propto^2 (1-2a)^2)$$

$$P = \frac{1}{2}\ \rho A V_\propto^3 (1-a)(1 - \ 1 + 4a^2 - 4a)$$

$P = \frac{1}{2}\ \rho A V_\propto^3 (4a - 8a^2 + 4a^3$ This is the power extraction

Condition for maximum power

$$\frac{dp}{dA} = 0$$

$$0 = \frac{1}{2}\ \rho A V_\propto^3 (4 - 16a + 12a^2)$$

$$= 4 - 16a + 12a^2$$

$$= 12a^2 - 16a + 4$$

$$a = 12a^2 - 12a - 4a + 4$$

$$= 12a(1-a) + a(-a+1)$$

$$a = 1, a = \frac{1}{3}$$

$P = \frac{1}{2}\ \rho A V_\propto^3 \frac{16}{17}$ is the power extraction of wind.

Let us construct a chart relating the wind speed to the power density and the output of the wind turbine assuming 30% efficiency of the turbine as shown in the following table.

Wind Speed kmph	**Wind speed m/s**	**Power Density Watts/m^2**	**Turbine output 30% efficiency**
1	0.278	0.013	0.004
10	2.778	12.860	3.858
25	6.944	200.939	60.282
50	13.889	1607.510	482.253
75	20.833	5425.347	1627.604
100	27.778	12860.082	3858.025
125	34.722	25117.348	7535.204

In the last column of the table, we have calculated the output of the turbine assuming that the efficiency of the turbine is 30%. However, we need to remember that the efficiency of the turbine is a function of wind speed. It varies with wind speed.

Now, let us try to calculate the wind speed required to generate power equivalent to 1 square meter PV panel with 12% efficiency. We know that solar insolation available at the PV panel is 1000 watts/m^2 at standard condition. Hence the output of the PV panel with 12% efficiency would be 120 watts. Now the speed required to generate this power by the turbine with 30% efficiency can be calculated as follows:

Turbine output required = 120 Watts/m^2

Power Density at the blades = 120/ (0.3) = 400 watts/m^2

Therefore, the wind speed required to generate equivalent power in m/s = $\left(\frac{400}{0.6}\right)^{1/3}$ =8.735805 m/s = 31.4489 kmph.

We have seen that the theoretical power is given by the following expression:

$$P_{theoretical} = \frac{1}{2}.\rho.A.v^3$$

However, there would be losses due to friction and hence, the actual power generated would be smaller. The co-efficient of power is defined as the ratio of actual power to the theoretical power. That is,

$$C_p = \frac{P_{actual}}{P_{theoretical}}$$

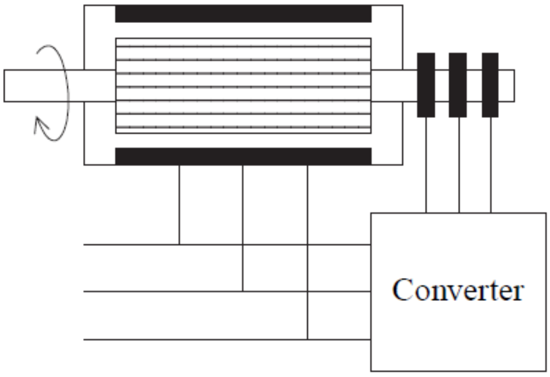
Another important ratio we need to know is the tip speed ratio. It is defined as the ratio of tip speed of blade to wind speed. That is,

$$T_R = \frac{\text{Tip speed of blade}}{\text{Wind speed}} = \frac{\text{w. radius}}{\text{velocity}} = \frac{\text{(radians/second). meters}}{\text{(meters/second)}}$$

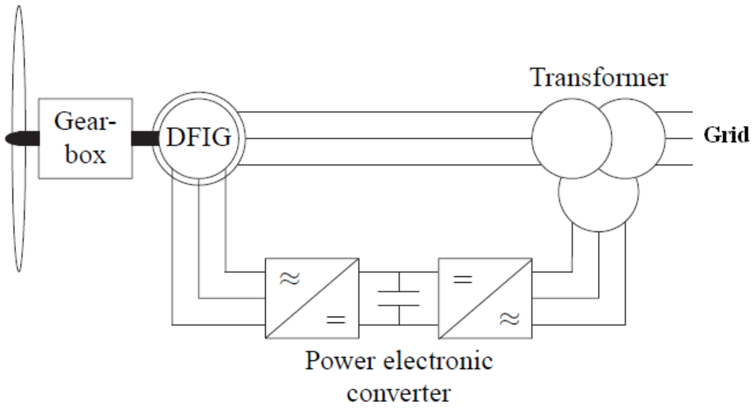
5. Explain about the Grid connection for wind?/ Describe the different schemes of WECS

(Nov 2012)

For variable-speed systems with limited variable-speed range, e.g.30% of synchronous speed, the DFIG can be an interesting solution. As mentioned earlier the reason for this is that power electronic converter only has to handle a fraction (20–30%) of the total power. This means that the losses in the power electronic converter can be reduced compared to a system where the converter has to handle the total power. In addition, the cost of the converter becomes lower. The stator circuit of the DFIG is connected to the grid while the rotor circuit is connected to a converter via slip rings, as shown in fig. below.



A more detailed picture of the DFIG system with a back-to-back converter can be seen in fig. below. The back-to-back converter consists of two converters, i.e., machine-side converter and grid-side converter that are connected “back-to-back.” Between the two converters a dc-link capacitor is placed, as energy storage, in order to keep the voltage variations (or ripple) in the dc-link voltage small. With the machine-side converter it is possible to control the torque or the speed of the DFIG and also the power factor at the stator terminals, while the main objective for the grid-side converter is to keep the dc-link voltage constant. The speed–torque characteristics of the DFIG system can be seen in fig. below As also seen in the figure, the DFIG can operate both in motor and generator operation with a rotor-speed range of $\Delta\omega max_r$ around the synchronous speed, ω_1.



A typical application, as mentioned earlier, for DFIG is wind turbines, since they operate in a limited speed range of approximately 30%. Other applications, besides wind turbines, for the DFIG systems are, for example, flywheel energy storage system [4], stand-alone diesel systems, pumped storage power plants, or rotating converters feeding a railway grid from a constant frequency public grid.

6. Write about the environmental aspects of wind?

(i) Audible noise:

The wind turbine is generally quiet. It poses no objectionable noise disturbance in the surrounding area. The wind turbine manufacturers generally supply the machine noise level data in dB versus the distance from the tower. This machine produces 55 dB noise at a 50-meter distance from the turbine and 40 dB at a 250-meter distance. The Table compares the turbine noise level with other generally known noise levels. The table indicates that the turbine at a 50-meter distance produces noise no higher than the average factory. This noise, however, is a steady noise. The turbine makes loud noise while yawing under the changing wind direction. The local noise ordinance must be complied with. There have been cases of noise complaints reported by the nearby communities.

Noise Level of Some Commonly Known Sources Compared with Wind Turbine

Source	Noise level
Elevated train	100 dB
Noisy factory	90 dB
Average street	70 dB
Average factory	60 dB
Average office	50 dB
Quiet conversation	30 dB

(ii) Electro Magnetic Interference (EMI):

Any stationary or moving structure in the proximity of a radio or TV tower interferes with the signals. The wind turbine towers, being large structures, can cause objectionable electromagnetic interference on the performance of the nearby transmitters or receivers. Additionally, rotor blades of an operating wind turbine may reflect impinging signals so that the electromagnetic signals in the neighbourhood may experience interference at the blade passage frequency. The exact nature and magnitude of such EMI depend on a number of parameters. The primary parameters are the location of the wind turbine tower relative to the radio or TV tower, physical and electrical properties of the rotor blades, the signal frequency modulation scheme, and the high frequency electromagnetic wave propagation characteristics in the local atmosphere.

(iii). Visual Impacts

Because they must generally be sited in exposed places, wind turbines are often highly visible; however, being visible is not necessarily the same as being intrusive. Aesthetic issues are by their nature highly subjective. Proper siting decisions can help to avoid any aesthetic impacts to the landscape. One strategy being used to partially offset visual impacts is to site fewer turbines in an y one location by using multiple locations and by using today's larger and more efficient models of wind turbines.

(iv). Bird life

Bird and bat deaths are one of the most controversial biological issues related to wind turbines. The deaths of birds and bats at wind farm sites have raised concerns by fish and wildlife agencies and conservation groups. On the other hand, several large wind facilities have operated for years with only minor impacts on these animals.

To try to address this issue, the wind industry and government agencies have sponsored research into collisions, relevant bird and bat behaviour, mitigation measures, and appropriate study design protocols. In addition, project developers are required to collect data through monitoring efforts at existing and proposed wind energy sites. Careful site selection is needed to minimize fatalities and in some cases additional research may be needed to address bird and bat impact issues.

(v). Other Concerns

Unlike most other generation technologies, wind turbines do not use combustion to generate electricity, and hence don't produce air emissions. The only potentially toxic or hazardous materials are relatively small amounts of lubricating oils and hydraulic and insulating fluids. Therefore, contamination of surface or ground water or soils is highly unlikely. The primary health and safety considerations are related to blade movement and the presence of industrial equipment in areas potentially accessible to the public.

7. Discuss the various factors to be consider for the site selection of wind turbine (Nov 2012)

Although wind power is a never ending green resource, assessment of environmental risks and impacts- which comprise the backbone of environmental policy- in the context of specific projects or sites often are necessary to explicate and weigh the environmental trade-offs that are involved. In the case of wind farms, a number of turbines (ranging from about 250 kW to 750 kW) are connected together to generate large amounts of power. Apart from the constraints resulting from the number of turbines, any site selection should think over the technical, economic, social, environmental and political aspects.

a. **Technical Considerations:** Many technical factors affect the decision making on site selection including wind speed, land topography and geology, grid structure and distance and turbine size. These technical factors must be understood in order to give pair-wise scores to sub-factors.
b. **Wind Speed:** The viability of wind power in a given site depends on having sufficient wind speed available at the height at which the turbine is to be installed. Any choice of wind turbine design must be based on the average wind velocity at the selected wind turbine construction site.
c. **Land topography and geology:** Wind farms typically need large lands. Topography and prevailing wind conditions determine turbine placement and spacing within a wind farm. In flat areas where there is nothing to interfere with wind flow, at least 2600-6000 m^2/MW may be required. Wind turbines are usually sited on farms that have slope smaller than 10-20%.
d. **Grid structure and distance:** The connection of wind turbines to an electricity grid can potentially affect reliability of supply and power quality, due to the unpredictable fluctuations in wind power output.
e. **Turbine size:** Required height for the installation of turbine above ground is one of the important factors that affect the annual energy generation. Turbine size is related with the energy output, because the bigger the turbine size is, the more wind it is exposed to.
f. **Economic Considerations** The economic sub factors that affect the site selection include capital cost, land cost and operational and management costs. It is important to make

economical evaluations by considering time value of money due to long periods of service life of wind farm projects.

g. **Capital cost** Construction, electrical connection, grid connection, planning, wind turbines, approvals, utilities and management are the main components of capital cost for wind farm projects.

h. **Land cost** For the site selection, main economic factor is the cost of the land where the wind farm is constructed; because, the cost of land primarily depends on the region, soil condition and the distance from the residential area.

i. **Operational and management cost:** There will be control functions such as supervisory control and data acquisition (SCADA) which will provide control of each wind turbine in O&M facilities. Business rates, maintenance expenses, rents, staff payments are main components of O&M costs.

j. **Electricity market:** Existing of an electricity market for the energy generated is an important factor affecting the economic benefits of the project. There should be energy demand in regions close to wind farms.

k. **Environmental Considerations:** The environmental sub factors that affect the site selection of a wind farm include visual impact, electromagnetic interference, wild life and endangered species and noise impact.

l. **Visual impact:** Wind turbines are located in windy places, and most of the time, those places are highly visible. To many people, those big towers with 2 or 3 blades create visual pollution. To minimize the impacts of visual pollution, many investors implement the actions.

m. **Wild life & endangered species:** Wind farms affect birds mainly through collision with turbines and associated power lines, disturbance leading to displacement including barriers to movement, and loss of habitat resulting from wind turbines. To minimise the risk of bird collision, site selection should be done precisely.

n. **Electromagnetic interference:** Electromagnetic interference is an electromagnetic disturbance that interrupts, obstructs, or degrades the effective performance of electronics or electrical equipment. Wind turbines may reflect, scatter or diffract the electromagnetic waves which in turn interfere with the original signal arriving at the receiver.

o. **Noise impact:** Noise can generally be classified according to its two main sources: aerodynamic and mechanical. Aerodynamic noise is produced when the turbine blades interact with eddies caused by atmospheric turbulence. Mechanical noise is generated by the rotor machinery such as the gearbox and generator. Noise could be reduced by better designed turbine blade geometry and by selection of proper operating conditions.

p. **Social Considerations:** Social factors that affect the selection of a site include public acceptance, distance from residential area and alternative land use options of candidate wind farm site. Public may oppose projects because of possible environmental or social effects. Distance from residential area gain importance not to interfere with social life during wind farm construction or operation.

q. **Regulatory boundaries:** There may be some national or international level regulation related with the construction and operation of wind farms. These regulations must be explored before evaluating the socio-political position of a wind farm project. Most of them probably change from region to region.

r. **Public acceptance:** Public is the most vital component of a region and their opposition to issues can lead to abolish proposed projects. Support of public for wind energy generation is expected to be high in general but proposed wind farms have often been met with strong local opposition.

s. **Land use:** Land use affects the decision of wind farm siting from two points of view. Firstly, there are some cases where no wind farms can be built although sufficient wind speed was detected. These cases are mainly related with land use or condition. Land related constraints include forest area, Wetlands, Land of high productivity, Archaeological sites, Aviation zones, Military zones etc.

t. **Distance from the residential area:** Noise and vibration stemming from the wind turbines may cause residents to suffer from sleep disturbance, headaches, visual blurring. Those types of complaints can be avoided if the wind turbines are sited a considerable distance from the residential area.

8. Explain the different types of wind turbine (Nov 2013)

A wind mill is a machine for wind energy conversion. A wind turbine converts the kinetic energy of the wind's motion to mechanical energy transmitted by the shaft. A generator further converts it to electrical energy, thereby generating electricity.

Wind mills are generally classified as –

- Horizontal axis type
- Vertical axis type,

depending on their axis of rotation. Horizontal axis wind mills further sub-classified as

- single bladed,
- double bladed,
- multiblade
- bicycle multibladed type,
- sail,
- wing.

The vertical axis wind mill is again sub-divided into two major types:

- (i) Savonius or 'S' type rotor mill (low velocity wind), (
- ii) Darrieus type rotor mill (high velocity wind), based on the working speed of the machine and the velocity ranges required by the machine for operation.

Vertical Axis Type Wind Mills

The Savonius Rotor:

The simplest of the modern types of wind energy conversion systems is the Savonius rotor which works like a cup anemometer. This type was invented by S.J. Savonius in the year 1920. This machine has become popular since it requires relatively low velocity winds for operation.

Constructional details and principle of operation.

It consists of two half-cylinders facing opposite directions in such a way as to have almost an S-shaped cross-section. The S shaped rotors are supported at top and bottom by two circular plates. These curved blades fixed on central pipe and free to rotate.

There two semi-circular drums are mounted on a vertical axis perpendicular to the wind direction with a gap at the axis between the two drums. Irrespective of the wind direction the rotor rotates such as to make the convex sides of the buckets head into the wind. However, instead of having two edges together to make an S-shape, they overlap to leave a wide space between the two inner edges, so that each of these edges is near the central axis of the opposite half cylinder, as shown in the figure. The main action of the wind is very simple; the force of the wind is greater on the cupped face than that on the rounded face. The wind curving around the back side of the cupped face exerts a reduced pressure much as the wind does over the top of an airfoil and this helps to drive the rotor. The wide slot between the two inner edges of the half cylinders, lets the air whip around inside the forward-moving cupped face and then around the inside of the backward moving face, thus pushing both in the direction of the rotation. The ratio of height to the overall diameter of the machine can be varied, but it is generally less than 3 to 1. Power coefficient of S rotor is low, but it might possibly be improved by changes in the design number and arrangement of the vanes. It has low efficiency, low speed and self starting capacity. It is not good for generating electricity because of low rpm. The rpm above 1000 is generally best for generating electricity.

Advantages

1. Performs at low wind velocity ranges
2. It has its low cut in speed (Wind speed required for switching electric power into the line) 3. Generator can be mounted on ground
3. Low system cost
4. Simple structure, easy to manufacture
5. Since it has vertical axis energy conversion system, it eliminates expensive power transmission system from the rotor to the axis
6. Yaw and Pitch control are not required. A constant speed vertical axis wind turbine, automatically stalls at high wind speeds
7. Overall weight of the turbine may be substantially less than that of conventional systems.

Disadvantages

1. This type of machine is too solid
2. It is not useful for a very tall installation because long drive shaft problems

Areas of Concern

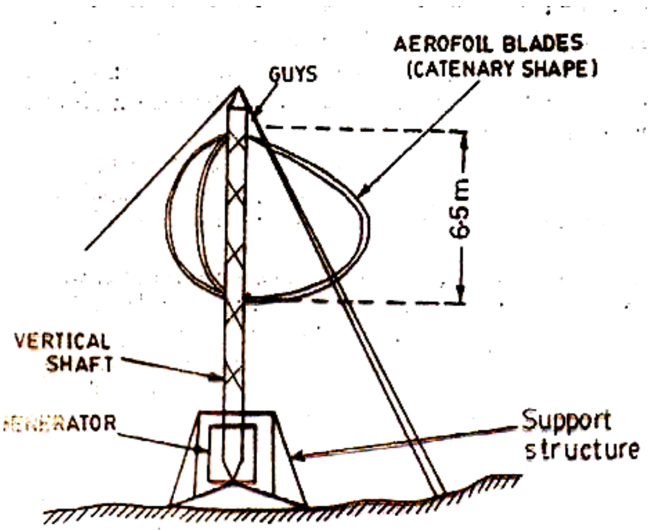
The Savonius rotor has moderately good efficiency and a satisfactory starting characteristics, the latter being particularly important for use with a positive displacement pumps. The rotor area requirement for getting the required amount of power is higher than any other systems. It is commonly used for pumping, and to operate small agricultural machines like winnowers, blowers, bird scarers, grinders etc. The another use of this type of wind energy conversion system is to use this machine along with Darrieus rotor for starting purposes.

The Darrieus type machines (High velocity wind).

This machine was invented originally and patented in 1925 by G.J.M. Darrieus a French Engineer and this concept has recently been given serious consideration once again. This type of windmills is already in use in Canada. As noted, a modern rapidly rotating propeller type windmill, by use of an efficient air foil, effectively intercepts large area of wind with a small blade area. The Darrieus wind mill is a type of vertical axis machine that has the same advantage. An additional advantage is that it supports its blades in a way that minimizes bending stresses in normal operation.

Constructional details and principle of operation.

In this type of machine, the blades are curved and attached to hubs on the vertical shaft at both ends to form a cage-like structure suggestive of an ordinary egg beater. The curved blade has the shape that a rope would take if subjected to centrifugal force in rapid rotation, some think like the shape of the rope in the exercise of skipping rope.



Vertical Axis Wind mill

Darrieus rotors have three symmetrical aerofoil blades, both ends of which are attached to a vertical shaft. Thus the force in the blade due to rotation is pure tension. This provides a stiffness to help withstand the wind forces it experience. The blades can thus be made lighter than in the propeller type. When rotating, these air foil blades provide a torque about the central shaft in response to a wind stream. This shaft torque is being transmitted to a generator at the base of the central shaft for power generation.

Characteristics of Darrieus Rotor

(i) Not self starting
(ii)High speed
(iii)High efficiency
(iv)Potentially low capital cost

Advantages

- ❖ The rotor blades can accept the wind from any compass.
- ❖ The machine can be mounted on the ground eliminating tower structures and lifting of huge weight of machine assembly
- ❖ It eliminates yaw control requirement for its rotor to capture wind energy
- ❖ Airfoil rotor fabrication costs are expected to be reduced over conventional rotor blade costs.
- ❖ The absence of pitch control requirements for synchronous operation may yield additional cost savings.
- ❖ The tip speed ratio and power coefficient are considerably better than those of the S-rotor but are still below the values for a modern horizontal-axis, twobladed propeller rotor.

Disadvantages

- It requires external mechanical aid for start up
- Rotor power output efficiency of a Darrieus wind energy conversion system is also some what lower than that of a conventional horizontal rotor
- Because a Darrieus rotor is generally situated near ground proximity, it may also experience lower velocity wind and yield less energy output.
- Because a Darrieus rotor encounters greatly varied local flow conditions per revolution, greater vibratory stresses are encountered which will affect rotor system life.
- Finally since a Darrieus rotor cannot be yawed out of the wind or its blades feathered, special high torque breaking system must be incorporated

Horizontal Axis Type Wind Mills

The blade of the wind mill may have a thin cross-section or the more efficient thick cross section of an aerofoil. The motion causing the "wind due to motion" here is the rotation of the blades. At the tip of the blades of a modern wind turbine, the velocity is about six times the wind velocity. This means that the blades are set rather flat at a small angle with the plane of the rotation and almost at right angles to the direction of the wind so that the effective wind properly approach from ahead of the leading edge. At other parts of the blade, between the tip and the axle, the velocity and the ideal set of the aerofoil is at a greater angle to the plane of rotation. Ideally the blade should be twisted, but because of construction difficulties this is not always achieved. Some of the horizontal axis type wind mills are briefly described below.

(1) Horizontal axis using two aerodynamic blades

In this type of design, rotor drives a generator through a step-up gear box. The blade rotor is usually designed to be oriented downwind of the tower. The components are mounted on a bedplate which is attached on a pintle at the top of the tower.

The rotor blades are continuously flexed by unsteady aerodynamic, gravitational and inertia loads, when the machine is in operation. If the blades are made of metal, flexing reduces their fatigue life. With rotor the tower is also subjected to above loads, which may cause serious damage. If the vibrational modes of the rotor happen to coincide with one of the natural mode of vibration of the tower, the system may shake itself to pieces. Because of the high cost of the blade rotors with more than two blades are not recommended. Rotors with more than two, say 3 or 4 blades would have slightly higher power coefficient.

(2) Horizontal axis propeller type using single blade.

In this arrangement, a long blade is mounted on a rigid hub induction generator and gear box. If extremely long blades (above say 6.0m) are mounted on rigid hub, large blade root bending moments may occur due to tower shadow, gravity and sudden shifts in wind directions. To reduce rotor cost, use of low cost counter weight is recommended which balances long blade centrifugally.

(3) Horizontal axis multiblade type.

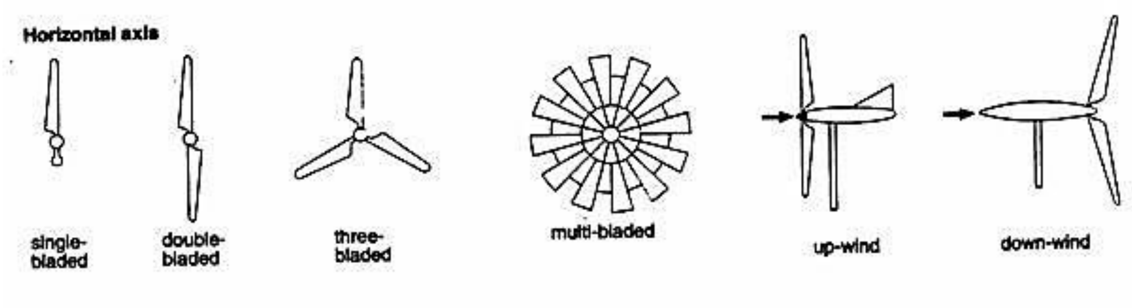
This type of design for multiblades as shown in fig are made from sheet metal or aluminium. The rotors have high strength to weight ratios and have been known to servive hours of freewheeling operation in 60 km/hr winds. They have good power coefficient, high starting torque and added advantage of simplicity and low cost.

(4)Horizontal axis wind mill – Dutch Type.

It is one of the oldest designs. The blade surfaces are made from an array of wooden slats which 'feather' at high wind speeds.

(5) Sail type.

It is of recent origin. The blade surface is made from cloth, nylon or plastics arranged as mast and pole or sail wings. There is also variation in the number of sails used.



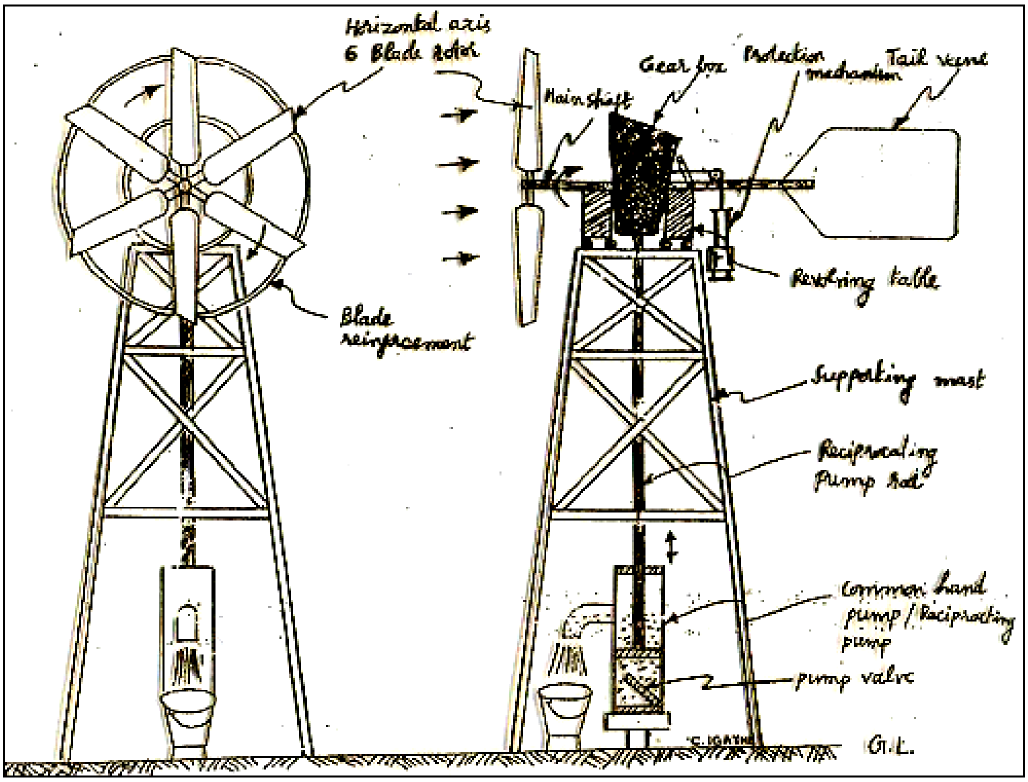
The horizontal axis types generally have better performance. They have been used for various applications, but the two major areas of interest are electric power generation, and pumping water.

Water Pumping Wind Mill:

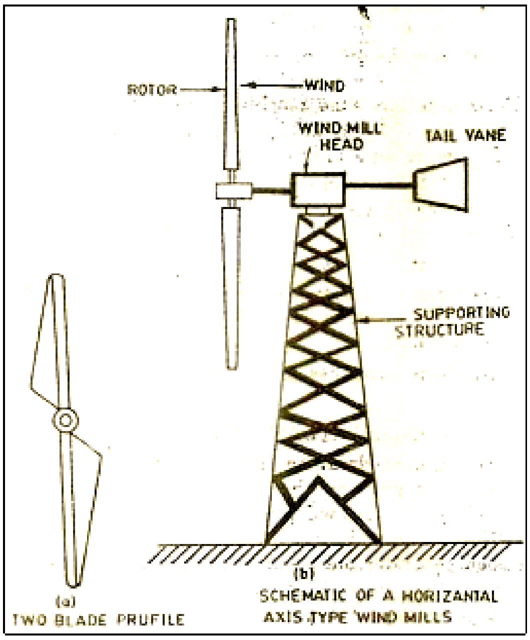
Conversion of wind energy into mechanical power is the technology of wind mill. The water pumping wind mill consists of a horizontal axis rotor with 10 – 12 blades. The pumps set consist of a piston with washer and valve arrangement. The rotor is mounted on the top of the tower to obtain sufficient wind velocity erected over a well at a height of about 10m and the pump is mounted in the well.

A crank mechanism enclosed in the gear box fixed to the shaft of the rotors converts the rotary motion into a reciprocating motion of the piston inside the pump body. This action causes the piston – washer – Valve assembly to suck the water from the well and discharge through the delivery pipe. When blowing winds are allowed to strike a set fitted rotor blades arranged in the form of rotor, makes it to rotate and the rotation is utilized to run the mechanism. The rotor is always made to face wind direction automatically by a tail vane arranged at right angle to the rotor plane. At normal operating conditions the tail vane is locked up with rotor consisting of a rope, pulley and counter weight mechanism.

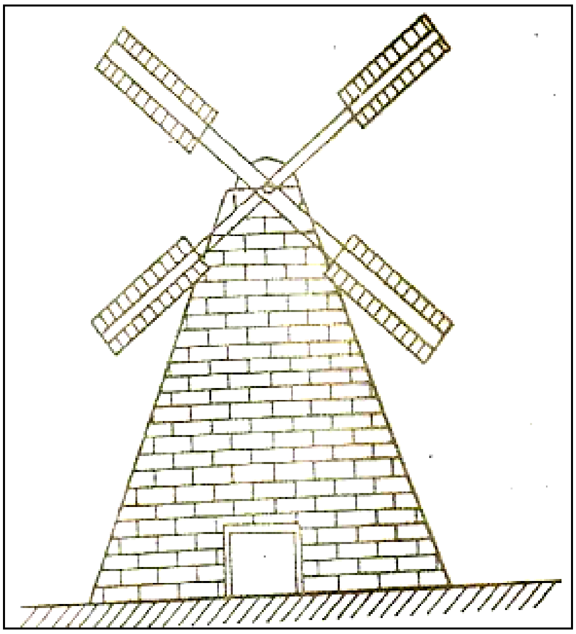
The windmill starts rotating at certain velocity and is known as cutting speed. High velocity winds cause damage to the rotor assembly and the damage is prevented by resting the rotor using safety mechanism. When the wind velocity exceeds the cut off limit, the relative shift between rotor and tail vane occurs and the safety mechanism automatically releases the connection between them. After the connection is broken, the rotor and tail vane come together and align in one plane parallel to the wind direction and resting of rotor takes place. To restore the operation of wind mill at normal wind speed, a man has to climb the tower and manually lock the tail vane with rotor. The wind speed at which the rotation occurs, ranges from 6-35 km/hr for pumping the water.



Water pumping Wind mill



Horizontal axis using two aerodynamic blades



Horizontal axis wind mill – Dutch Type

Pump driving mechanism for piston rods are aligned in line of pump shaft so that a 3600 rotation of the entire rotor assembly is possible when the pump is in operation. Common hand operated bore well pump can also be attached to the wind mill with a min. modification. Pumped water can directly let in to the channel for irrigation or directed to over head storage tank.

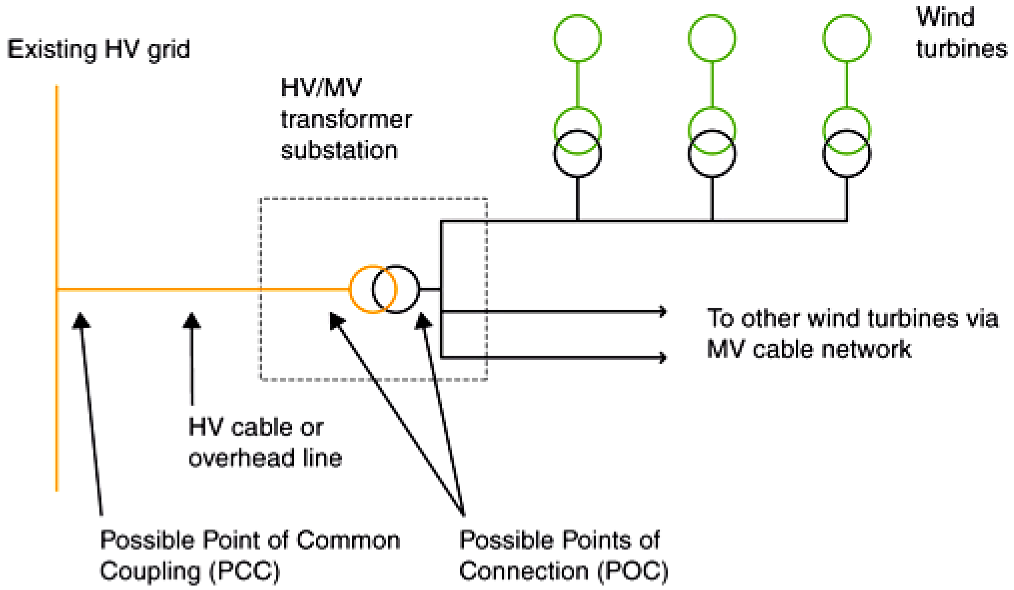
9. **Describe the electrical layout of typical wind form by means of single line diagram**

(April/May 2012)

An offshore wind farm electrical system consists of six key elements:

- Wind turbine generators;
- Offshore inter-turbine cables (electrical collection system);
- Offshore substation (if present);
- Transmission cables to shore;
- Onshore substation (and onshore cables); and
- Connection to the grid.

Electrical layout of a wind form bye means of single line diagram is show below



The design of the electrical system is determined by the characteristics of the wind turbine generators and of the network to which the project is to be connected, as well as regulations imposed upon it, notably through Grid Codes. The network operator controls the grid to meet its operational objectives and also requires a degree of control over large generators (which may include offshore wind farms). Additionally, the wind farm must be designed to respond appropriately to grid faults. These demands can be expected for any large wind farm located offshore.

Wind turbine control and electrical systems are constantly evolving to provide improved characteristics and fault response for the purpose of grid integration. Nevertheless, the wind farm electrical system can be expected to have additional functional requirements in addition to the basic transmission from turbines to the grid connection point.

OFFSHORE SUBSTATIONS

Offshore substations are used to reduce electrical losses by increasing the voltage and then exporting the power to shore. Generally a substation does not need to be installed if:

- The project is small (~100 MW or less);
- It is close to shore (~15 km or less); or
- The connection to the grid is at collection voltage (e.g. under 36 kV).

Most early offshore wind projects met some or all of these criteria, so were built without an offshore substation. However, most future offshore wind farms will be large and/or located far from shore, and so will require one or more offshore substations.

Offshore substations typically serve to step-up the voltage from the site distribution voltage (30 to 36 kV) to a higher voltage (say 100 to 220 kV), which will usually be the connection voltage. This step-up dramatically reduces the number of export circuits (subsea cables) between the offshore substation and the shore. Typically, each export circuit may be rated in the range 150 to 200 MW.

Such substations may be configured with one or more export circuits. Future units will be larger and more complex. To date, no standard substation layout has yet evolved.

For projects located far from the grid connection point, or of several hundred megawatts in capacity, AC transmission becomes costly or impossible, due to cable-generated reactive power using up much of the transmission capacity. In such cases, high voltage DC (HVDC) transmission is becoming an option. Such a system requires an AC/DC converter station both offshore and onshore; both stations are large installations.

ONSHORE SUBSTATIONS

Design of the onshore substation may be driven by the network operator, but there will be some choices to be made by the project developer. Generally, the onshore substation will consist of switchgear, metering, transformers and associated plant. The onshore substation may also have reactive compensation equipment, depending on the network operator requirements and the design of the offshore network.

SUBSEA CABLES

Subsea cables are of well-established design. Each circuit runs in a single cable containing all three phases and optical fibre for communications, with a series of fillers and protective layers and longitudinal water blocking to prevent extensive flooding in the event of the external layers failing.

Inter-turbine (array) cables are typically rated at 30 to 36 kV and installed in single lengths from one turbine to its neighbour, forming a string (collection circuit) feeding the substation. Each collection circuit is usually rated up to 30 MW. Export cables are of similar design but for higher voltage, typically 100 to 220 kV. Cables are terminated at each structure through a vertical tube from seabed to above water level (J-tube or I-tube) and into conventional switchgear.

Long-term reliability of the subsea cables is a major concern, addressed mainly by ensuring the safe burial of the cables at a depth that avoids damage from trawlers and anchors and the exposure of cables to hydrodynamic loading.

10. Performance of the wind turbines (Nov 2013)

The performance of a wind rotor is usually characterized by the variations in its power coefficient with the tip speed ratio (Fig. 6.10). As both these parameters are dimensionless, the cp-λ curve (Fig. 6.10) will represent the rotor performance irrespective of the rotor size and site parameters.

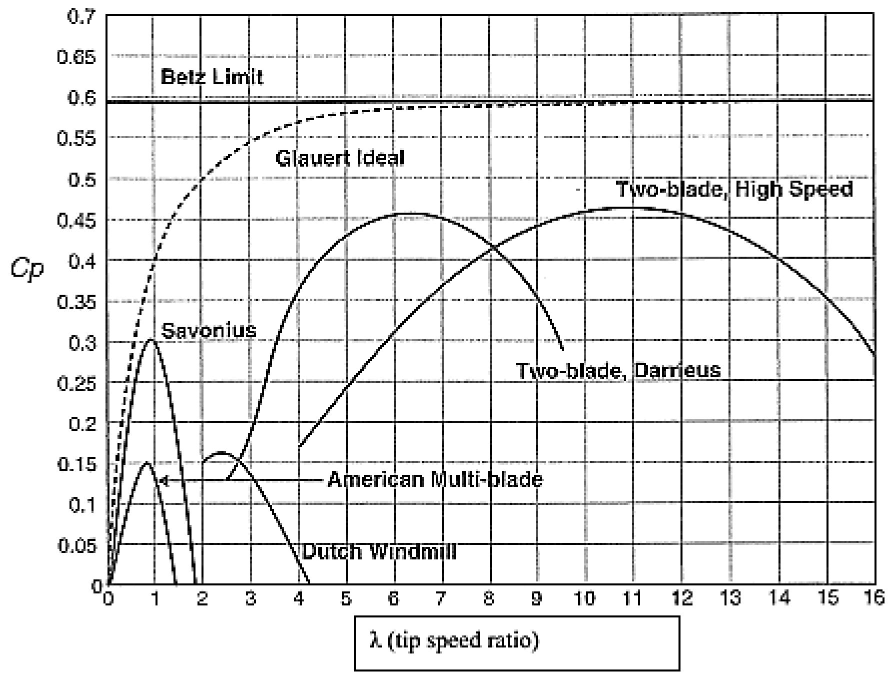


Fig. 6.10 Power coefficient versus tip speed ratio for different wind turbine configurations.

PONDICHERRY UNIVERSITY QUESTIONS

2 MARKS

1. How wind turbine is are classified? (April/May 2012)
2. What are the disadvantages of wind power generation system?(Nov 2013)
3. What is meant by pitch angle? (April/May 2016)
4. What is Power coefficient?(Nov 2012)
5. List the various factors to be consider for the site selection of wind turbine (Nov 2013)
6. What are the types of rotors for HAWT?(Nov 2012)

11 MARKS

1. Write the detailed report on the performance of the wind turbine (Nov 2013)
2. Explain the different types of wind turbine (Nov 2013)
3. With neat diagram how the wind energy in converter in to electrical energy(April/May 2012)
4. Describe the electrical layout of typical wind form by means of single line diagram (April/May 2012)
5. Discuss the various factors to be consider for the site selection of wind turbine **(Nov 2012)**
6. Performance of the wind turbines (Nov 2013)
7. Describe the different schemes of wind electric generation (Nov 2012)

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

Subject Name: **Renewable Energy Sources** Subject Code:**EEE 12**

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UNIT IV: OCEAN &TIDAL ENERGY

Ocean and Tidal energy conversion- working principle of OTEC-And ers on closed cycle OTEC system- Application of Merits and demerits of ocean energy technologies. Tides-spring tide, neap tide, daily and monthly variation, Tidal range, Tidal Power- Types of tidal power plants, single basin & double basin schemes, main requirements in tidal power plants, energy storage, prospects of tidal power.

2- MARKS

1. What is the basic principle of Ocean Thermal Energy Conversion (OTEC)?

Sun radiation warming up water of ocean surface is creating a temperature difference this difference ΔT is fairly low About 10K. Whereas 25K at best in tropical seas (surf – 0.5km/1km). This temperature difference is used to vaporize the low boiling point liquid like ammonia (15K) with the help of heat exchanger, which is then used for power generation.

2. What is the cause of tides? And what its tidal range.

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 the water 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. Tidal range is expressed as the difference in water levels between two consecutive high tides and low tides.

3. What are the limitations of tidal energy power plant?(Nov 2012)

1. Economic recovery of energy from tides is feasible only at those sites where energy is concentrated in the form of tidal range of about 5m or more and the geography provides a favourable site for economic construction of a tidal plant. Thus it is site specific.
2. Due to mismatch of lunar driven period of 12 hours 25 min and human (solar) period of 24 hours, the optimum tidal power generation is not in phase with demand.
3. Changing tidal range in two-week periods produces changing power.
4. The turbines are required to operate at variable head.

5. Requirement of large water volume flow at low head necessitates parallel operation of many turbines.
6. Tidal plant disrupts marine life at the location and can cause potential harm to ecology.

4. List the classification of OTEC

a. based on location.
1. Land based plant
2. Shelf based plant
3. Floating plant

b. based on cycle
1. Open cycle
2. Closed cycle
3. Hybrid cycle

5. List benefits of OTEC.

a. Air conditioning
b. Chilled soil agriculture
c. Aquaculture
d. Desalination

6. List disadvantages of OTEC.

a. Degradation of heat exchanger performance as dissolved gases.
b. Degradation of heat exchanger performance by microbial fouling
c. Improper sealing
d. Parasitic power consumption by exhaust compressor

7. .What are the various ways of creating tidal energy?

a. Tidal Barrage
b. Tidal fences
c. Tidal turbines

8. List the various types of turbines used in tidal power station.

a. Buld turbine
b. Rim turbine
c. Tubular turbines

9. What are the components of tidal power station?

a. Barrage
b. Turbines
c. Sluices
d. Embankments

10. List any four advantages of tidal power generation.

a. Renewable and sustainable energy
b. No liquid or Solid pollution
c. Little visual impact
d. Reduces dependence upon fossil fuels

11. What is meant by tidal current energy

Tidal currents are the flow of water during changing tidal level. The tidal currents flow in horizontal direction and have kinetic energy. This energy is called tidal current energy.

12. What is meant by tidal current

The tidal rise and fall of water is accompanied by periodic horizontal to and fro motion of water called tidal currents.

13. Define tidal range.

The tidal range is the difference between consecutive high and low tide water levels. It is denoted by R unit is metre.

R= (High tide level) – (low tide level) m

14. Define the following terms

a. Spring tides
b. Neap tides

a. Spring tides: The tidal range is maximum on full moon and new moon and such tides are called spring tides.

b. Neap tides: The tidal range is minimum on first quarter and third quarter moon and such tides are called the neap tides.

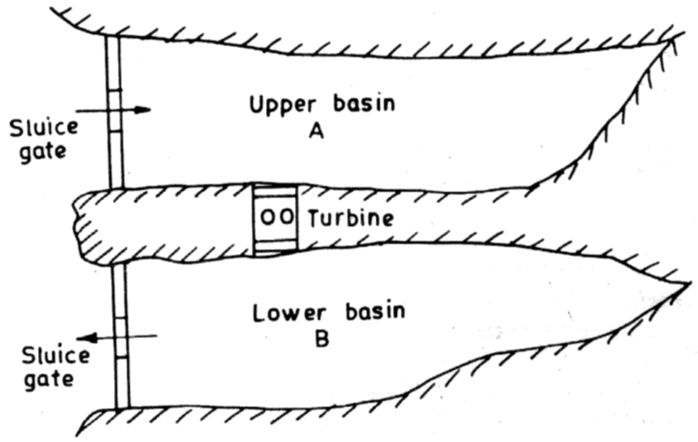
15. What are the types of tidal power plants?(April/May 2012)

a. Single basin single effect plant
b. Single basin double effect plant
c. Double basin with linked basin operation
d. Double basin with paired basin operation

16. What are the disadvantages of wave energy generation?

a. Wave energy equipment must be capable of withstanding very reverse peak stress and storms
b. Wave energy equipments are complicated
c. Capital investment, cost of maintenance repair and replacement growth of biological organisms are other problems
d. Energy is available on the ocean. The extraction equipment must be operated in a marine environment

17. Draw the double basin arrangement of tidal power plant (Nov 2013)



11 MARKS

1. **Write about ocean thermal energy conversion system.(OTEC)**

The ocean thermal energy concept was proposed as early as 1881 by the French physicist Jacques d‘ Arsonval. In this indirect form of solar energy at sea, collection and storage are free. The surface of the water acts as the collector for solar heat while the upper layer of the sea constitutes infinite heat storage reservoir. Thus heat contained in the oceans, which is solar in origin could be converted into electricity by utilizing the fact that the temperature difference between the warm surface water of the tropical oceans and the colder waters in the depths is about 20-25°K. Warm surface water could be used to heat some low boiling organic fluid, the vapour of which would run a heat engine. The exit vapour would condensed by pumping cold water from the deeper regions. The amount of energy available for ocean thermal power generation is enormous, and is replenished continuously. Solar energy absorption by the water takes place according to Lambert‘s law of absorption, which states that each layer of equal thickness absorbs the same fraction of light that passes through it.

Mathematical

$$-\frac{dI_{(x)}}{dx} = kI \qquad \text{Or} I_{(x)} = I_o e^{-kx}$$

Where Ioand I(x) are the intensities of radiation at the surface (x = 0) and at a distance x below the surface. K is an extinction coefficient (or absorption coefficient) that has the unit , K has values of 0.05 for very clear fresh water, 0.27 for turbid fresh water and 0.50 for very salty water. Thus the intensity decreases exponentially with depth and, depending upon K, almost all of the absorption occurs very close to the surface of deep waters.

Because of heat and mass transfer at the surface itself, the maximum temperatures occurjust below the surface. Considering deep water in general, the high temperatures are at the surface, whereas deed water remains cool. In the tropics, the ocean surface temperature often exceeds 25°C, while 1 km below, the temperature is usually not higher than 10°C. Water density decreases with an increase in temperature (above 4°C where pure water‘s density is maximum, decreasing again below this temperature, the reason ice floats). Thus there will be no thermal convection currents between the warmer, lighter water at the top and deep cooler, heavier water. Thermal conduction heat transfer between them across the large depths, is too low to after this picture, and thus mixing the retarded, so the warm water stays at the top and the cool water stays at the bottom. It is said, therefore, that in tropical waters there are two essentially infinite heat reservoirs, a heat source at the surface at about 27°C and a heat sink, some 1 km directly below, at about 4°C; both reservoirs are maintained annually by solar incidence. The concept of ocean thermal energy conversion (OTEC) is based on the utilization of this temperature difference in a heat engine to generate power.

The surface temperatures (and temperature differences) vary both with latitude and season, both being maximum in tropical, subtropical, and equatorial waters i.e., between the two tropics, making these waters the most suitable for OTEC systems. Several such plants are built in France after World War II (the largest of which has a capacity of 7.5 MW). With a 22°K temperature difference between surface and depths, such as exists in warmer ocean areas than in north sea, the Carnot efficiency is around 7%. This is obviously very low, and comparable to that expected from a flat plate collector. In fact, by the time the overall efficiency has been reduced by using a practical engine (operating on a Rankine cycle say) together with heat exchangers, the propositions might seem hopeless. One major difference between these two heat sources is that solar energy arrives with a 10W power density, and requires a large acreage of flat-plate collector.

Whereas on ocean thermal gradient source can operate with a small area collector by pumping sufficient water through the heat collector. Indeed the attraction of the solar sea power plant lies in its present day engineering feasibility and possible competitive cost with fossil fuel power stations. As stated the idea of ocean thermal energy conversion with a suitable working fluid was originated by d‘ Arsonval, but the technical feasibility of the open cycle system was demonstrated by Claude with an installation on the south coast of Cuba in 1929.

It was a remarkable achievement at the time. The electric power generated was 22 kilowatts with an overall efficiency more than 1 per cent. The hot and cold water were conducted through the long pipes to the machinery ashore. With the limited technology and cheap fuel at that time, there was then little prospects for economic feasibility. A larger installation with two units totalling 7 megawatts was constructed on the Ivory coast by the French in 1956, but encountered troubles and was abandoned. The process of OTEC, requires that the warm surface water and cold water from depth (about 1000-1500 m), be brought into proximity so they act as the heat source and the heat sink, respectively for a heat engine.

In other words, solar energy collected and stored as heat by the world‘s major oceans, can be converted into electricity through a generation process similar to that of conventional power plants, except that in the case of OTEC, no depletable fuel is required. Furthermore, although there is some seasonal variation in the ocean thermal resource at a given OTEC power plant location, there is little diurnal variation.

Accordingly OTEC power plants are analogous to solar hydropower plants in that they smooth out the diurnal intermittence of the solar radiation, in contrast to other electric power options. OTEC power plants provide a potentially substantial renewable source of base load electricity, .albeit located mainly at sea. Although it is possible to find good land sites where OTEC power plants can be located, by bringing the warm and cold water onto shore via aqueducts (artificial cannal/conduit), it is clear that such opportunities will be much limited on a global basis than the ample opportunities for generating substantial amounts of OTEC electricity abroad floating OTEC platforms. This is both because of the special technical requirements for on shore OTEC plants and because of the limited market potential (at least in the near term) for OTEC electricity at such sites.(n shore OTEC power plants will be viable mainly at locations where three requirements are all simultaneously satisfied with satisfactory economics:

(i) Coastal zone land must be available,
(ii) Sea floor must descend sufficiently rapidly from the shore based plant location; and
(iii)The seasonal availability of warm and cold water without undue gradation by the warm and cold water effluents from the OTEC plant must meet certain criteria. In any event, it is probable that available and attractive on shore and near shore OTEC power plant location will be populated early in the development and implementation of the OTEC concept, both as convenient locations for pilot and demonstration plants and because they will constitute attractive intermediate markets for OTEC electricity and by products.

OTEC power generation system gives less efficiency, as stated above. However, because of the OTEC requirement for paas1tic power (such as for pumping up the cold water supply) and other losses, the achievable net conversion efficiency is only about 2.5 percent (Carnot efficiency 7‘). This compares a net efficiencies of 30 to 40% associated with conventional power Some engineers question whether such as an extremely low net efficiency will ever allow OTEC to become economically viable. However, it is important to consider the matter in more sophisticated terms than net efficiency;since in the case of OTEC there is no fuel cost, only the requirement to pay for circulating much more warm and cold water, than is normally associated with power generation. This means that extensive areas heat exchangers will be required for ―closed cycle‖ OTEC plants (which would employ a working fluid such as ammonia) or that degasifies (to remove gases dissolved in the sea water) and tremendous turbines would be required for ―open cycle‖ OTEC plants that would operate by the flash evaporation of sea water. Thus, although the net efficiency of the JEC plant must certainly be positive and as high as is readily attainable,the key economics question is the resulting cost of OTEC electrical energy, not the actual value of the net efficiency.

2. Methods Of Ocean Thermal Electric Power Generation:

There are two rather different methods for harnessing ocean thermal differences. One is the open cycle, also known as the Claude cycle, and other is the closed cycle system, also known as the Anderson cycle.

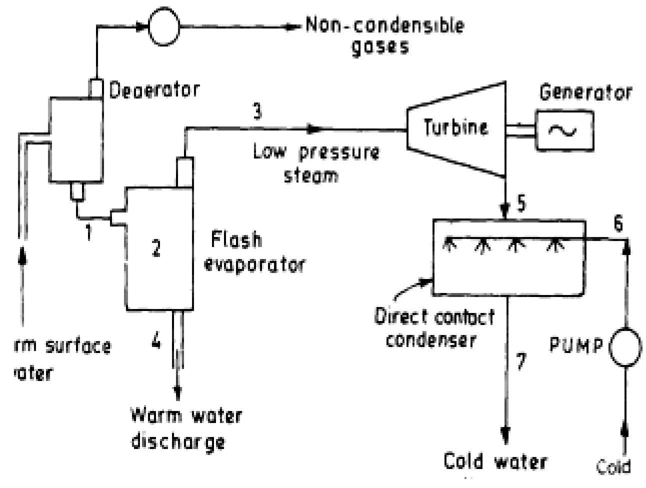
In the closed cycle system**,** a liquid working fluid, such as ammonia or propane, is vaporized in an evaporator (or boiler); the heat required for vaporization is transferred from the warm ocean surface to the liquid by means of a heat exchanger‘)

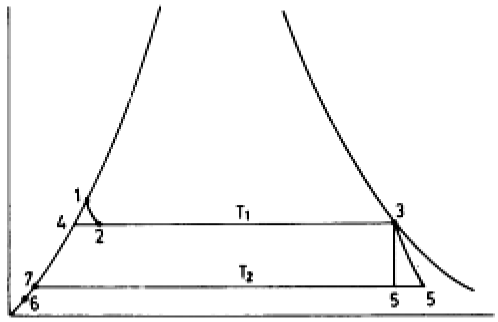
The high-pressure vapour leaving the evaporator drives an expansion turbine, similar to a steam turbine that it is designed to operate at a lower inlet pressure. The turbine is connected to an electric generator in the usual manner. The low pressure exhaust from the turbine is cooled and converted back into liquid in the condenser. The cooling is achieved by passing cold, deep ocean water, from a depth of 700 to 90O or more, through a heat exchanger. T The liquid working fluid is then pumped back as high pressure liquid to the evaporator, thus closing the In the open-cycle turbine system, water is the working fluid. The warm surface water is caused to boil by lowering the pressure, without supplying any additional heather low-pressure steam produced then drives a turbine, and the exhaust steam is condensed by the deep colder water and is discarded. A heat exchanger is not required in the evaporator and direct-contact between the exhaust steam and a cold- water spray makes a heat exchanger as necessary in the condenser. On the other hand, because of the low energy content of the low pressure steam, very large turbines or several smaller units operating in parallel would be required to achieve a useful electric power output. The Claude cycle or open cycle which is older one, utilizes the vapour pressure of sea water itself as the working medium and has been demonstrated to be practicable.

The other method, a closed cycle known as the Rankine cycle, uses a working fluid with higher vapour pressure (such as ammonia, hydrocarbon or halocarbon) at the temperature available. This cycle is favoured for the future development in expectation of higher efficiency. The first published work on OTEC by *d'.* Arsonvol in 1881, suggs a closed cycle, and that article proposed sulfer di-oxide (SO2) as the working fluid. However, the first OTEC experiments by Claude in the 1920s utilized on open cycle where sea water was evaporated under a partial vacuum.

3. Explain In Detail About Open Cycle OTEC System (Claude Cycle)

'Open cycle' refers to the utilization of sea water as the working fluid, wherein sea water is flash evaporated under a partial vacuum. The low pressure steam is passed through a turbine, which extracts energy from it, and then the spent vapour is cooled in a condenser. This cycle drives the name _open' from the fact that the condensate need not be returned to the evaporator, as in the case of the _closed cycle'. Instead, the condensate, can be utilized as desalinated water if a surface condenser is used, or if a spray (direct-contact) condenser is used, the condensate is mixed with the cooling water and the mixture is discharged back into the ocean. &schematic diagram of the open cycle system is shown in Fig.





Schematic of the OTEC open cycle **T.S. diagram corresponding to**

Its corresponding T-S diagram is also Fig. Schematic of the OTEC open cycle. shown in the Fig. In the cycle shown warm surface water at say 27°C is admitted into an evaporator in which the pressure is maintained at a value slightly below the saturation pressure

At the new pressure, water which is entering the evaporator gets _super heated'. As shown in Fig. the warm water which is at 27°C, has a saturation pressure of 0.03619 kg/cm2 (0.0356 bar) (point 1).

The evaporator pressure is 0.03213 (0.0317 bar), which corresponds to 25°C saturation temperature. This temporarily superheated water undergoes volume boiling (as opposed to pool boiling which takes place in conventional boilers due to an immersed heating surface), causing that water to partially flash to steam to an equilibrium two phase condition at the new pressure and temperature of 0.032 13 kg/km2 and 25°C (point 2). Process 1-2 is a throttling and hence constant enthalpy process.

The low pressure in the evaporator is maintained by a vacuum pump that also removes the dissolved non-condensable gases from the evaporator. At point 2, the evaporator contains a mixture of water and steam of very low quality. The steam is separated from the water as saturated vapour at 3.

The remaining water is saturated at 4 and is discharged as brine back to the ocean. The steam at 3, has a very low pressure and high specific volume (0.03213 kg/cm2,43.40 m3/kg), as compared to conventional fossil power plant, which has about 160 kg/cm2 pressure and 0.021 m3/kg specific volume.

The steam expands in a specially designed turbine that can handle such conditions to 5. The condenser pressure and temperature at point 5 are of the order of 0.01729 kg/cm2 (0.0 17 bar) and 15°C. A direct contact condenser is used as the turbine exhaust steam will be discharged back to the ocean in the open cycle system. In the condenser, the exhaust steam is mixed with cold water from the deep cold water pipe at 6, which results in near saturated water at 7. This water is allowed to discharged to the ocean.

The cooling water from the deep ocean which is at about 11°C, on reaching the condenser, its temperature rises to about 15°C, due to heat transfer between the progressively warmer outside water and cooling water inside the pipe, as it ascends towards the top. It can be seen that very large ocean water mass and volume flow rates are used in open OTEC systems and that the turbine is a very low pressure until that receives steam with specific volumes more than 2000 times that in a modern fossil power plant. Thus the turbine resembles the few lost exhaust stages of a conventional turbine and is thus physically large.Because of the need in the open cycle to harness the energy in low pressure steam, extremely large turbines (compared to wind turbines) must be utilized. Further-more degasifiers (deaerators) must be used to remove the gases dissolved in the sea water unless one is willing to accept large losses in efficiency.

On the other hand, since there are no heat transfer problems in the evaporator, the problem of bio-fouling control is minimized. The cost of an open-cycle system for providing substantial number of megawatts is presently regarded by most OTEC workers as being significantly greater than for closed cycle system. The turbine cost constituted almost half the cost of the power system, but may be amenable to reductions that could result from design innovations.

4. Explain In Detail About The Closed Or Anderson, OTEC Cycle

A schematic of a closed-cycle OTEC power plant is shown in Fig. Heat exchanger known as evaporators and condensers are a key ingredient, since extensive areas of material are needed to transfer significant amounts of low quality heat of the low temperature differences being exploited.

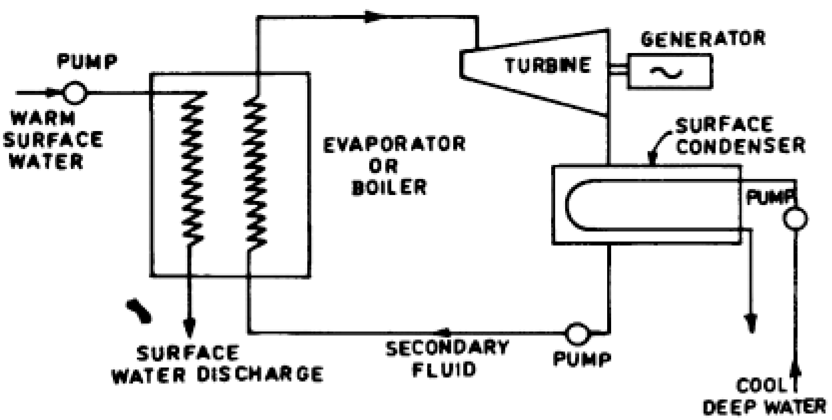


Fig. Schematic of an OTEC closed cycle system.

In other words, large volumes of water must be circulated through the OTEC power plant, requiring commensurately large heat exchangers. The actual components employed in an OTEC closed cycle system would appear more like the hardware illustrated in **Fig.2**another closed cycle schematic. This cycle requires a separate working fluid that receives and rejects heat to the source and sink *via* heat exchangers (boiler or evaporator and surface condenser). The working fluid may be ammonia, propane, or a Freon. The operating of such fluids at the boiler and condenser temperatures are much higher than those of water, being roughly10 kg/cm2 (10 bar) at the boiler, and their specific volumes are much lower, being comparable to those of steam in conventional power plants.

Such pressures and specific volumes result in turbines that are much smaller and hence less costly than those that use the low pressure steam of the open cycle. The closed cycle also avoids the problems of the evaporator. It however, requires the use of very large heat exchangers (boiler and condenser) because, for an efficiency of about 2 percent, the amounts of heat added and rejected are about 50 times the output of the plant. In addition, the temperature differences in the boiler and condenser must be kept as low as possible to allow for the maximum possible temperature difference across the turbine, which also contributes to the large surfaces of these units.

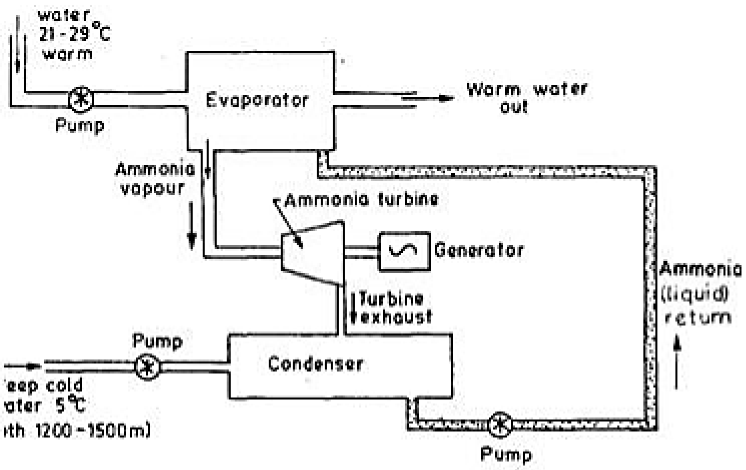


Fig. 2.Schematic of a closed OTEC ammonia cycle.

The closed cycle approach was first proposed by Barjot in 1926, but the most recent design was by Anderson and Anderson *in* the 1960s. The closed cycle is sometimes referred to as the Anderson Cycle. In the cycle propane was chosen as the working fluid. The temperature difference between warm surface and cool surface was 20°C. The c surface was at about 600 m deep. Propane is vaporized in the boilei evaporator at about 10 kg/cm2 (10 bar) or more and exhausted in 1 condenser at about 5 bar. Instead of usual heavier and more expensive shell and tube h exchangers, the Anderson OTEC system employs thin plate type h exchangers, which minimizes the mass and the amount of material a hence cost. The heat exchangers are placed at depths where the sta pressure of the water in either heat exchanger roughly equals i pressure of the working fluid, this helps in reducing the thickness of plates.

A fundamental requirement in closed cycle systems is to trans. heat efficiently across the heat exchanger surfaces constituting t evaporators and condensers, so as to achieve a high value of overall h transfer coefficient (U) measured in watts per kelvin per square meter or W/°K/m2. For the evaporation, this overall heat transfer coefficient is a measure of how effectively heat is transferred sequentially from s water through the heat exchanger materially (a metallic alloy) a hence to the working fluid *(e.g.,* ammonia). For the condenser, an over U characterized the reverse heat transfer process. In an ocean environment, it is likely that a layer of slime known as ―bio fouling‖ will eventually accumulate on the water side of the he exchangers. Such slime is first comprised or micro-organisms, at which stage, the bio fouling is called micro fouling‖. Subsequently, if the slime is not removed, additional bio-fouling in the form of micro-organism will become attached, augmenting the slime layer. The occurrence micro-fouling seems to be a pre-requisite for the attachment of macro organisms. A film of corrosion and possibly of calcareous (e.g. minerals deposits can also accumulate on the water side (and conceivably through leakage—even on the working fluid side of the heat trans surfaces). The total formulation of bio-fouling, corrosion, and so on, referred to a ―fouling‖ (or scaling) and will tend to inhibit heat trans through it.

The ―fouling factor‖ is a measure of the thermal resistance Rf‛of a fouling film. This thermal resistance is the reciprocal of t corresponding heat transfer coefficient 'hf' of the fouling film. To maintain viable OTEC heat exchangers, provisions must be made to inhibit the formation of fouling layers and to remove any significant fouling that forms. Removal can be accomplished by periodically cleaning the heat exchanger surfaces through mechanical, chemical or other means. Although both closed-and open cycle turbine systems are being explored, it appears that closed-cycle systems offer the most promise for the near future. Each of the possible working fluids (i.e. ammon and propane) has advantages and disadvantages.

5. Site Selection For OTECS

In selecting a site for an OTEC facility, the primary consideration is, of course, a significant temperature difference—at least about 20°C—between surface and deep ocean waters (for 700-900 m depth or more) that will permit year round operation

The greater the difference, the lower will be the cost of generating electricity. The best sites are in the tropical belt between about 20°N and 20°S latitude. There are, however, several locations outside this area that might be suitable for OTEC plants. In choosing a site, consideration should be given to the potential for bio-fouling effects as noted earlier.

As a general rule, an OTEC plant would be located offshore in order to provide access to the deep colder water. However, an ideal situation might be one where the shoreline dropped steeply to a considerable depth. Most of the installation could then be more conveniently build on land.

6. Explain in detail about Hybrid Cycle ocean cycle thermal energy conversion system

There are several variations on the standard OTEC open-cy system.

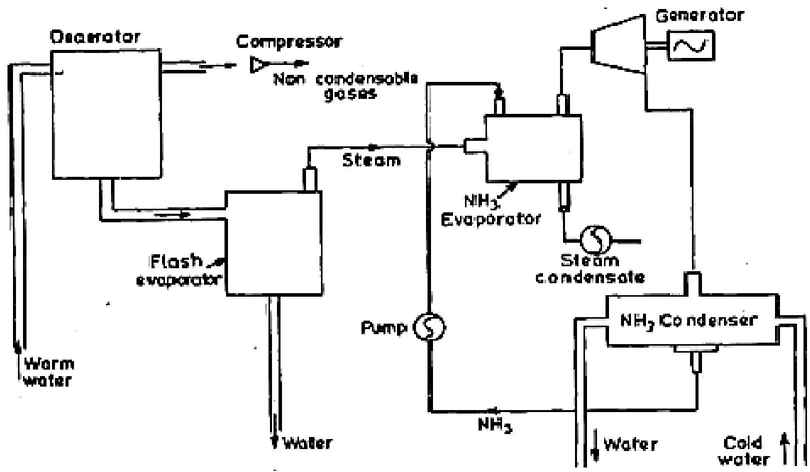


Fig. Hybrid Cycle

One variation is the hybrid cycle which is an attempt combine the best features and avoid the worst features of the open closed cycles. First, as shown in Fig., sea water is flash evaporated to steam, as in the open cycle. The heat in the result steam is then transferred to ammonia in an otherwise conventional closed Rankine cycle system

7. Prospects of Ocean Thermal Energy Conversion In India

The OTEC project cell established at IIT, Madras has completed the preliminary feasibility study for establishing a, 1 MW OTEC plant in Lakshadeep Island at Minicoy. The OTEC works on the principle of utilizing the temperature difference of sea water at depth and that at the surface.

The surface sea water is used to vaporize a low boiling chemical which drives, a turbogenerator. Thevaporized chemical is then compressed; it is condensed by using cold sea water from depth. Preliminary oceanographic studies on eastern side of Lakshadeep Island suggest the possibility of the establishment of shore based OTEC plant at the island with a cold water pipe line running down the slope to a depth of 800—1000 m.

Both the island has large lagoons on the western side. The lagoons are very shallow with hardly any nutrient in the sea water. The proposed OTEC plant will bring up the water from 1000 m depth which has high nutrient value. After providing cooling effect in the condenser, a part of deep sea water is proposed to be diverted to the lagoon for the development of aqua culture. A hydro graphic survey of the proposed site was undertaken by National Hydro graphic Office, Dehra Dun. The preliminary assessment of survey indicates the availability of suitable conditions for establishment of OTEC plant.

8. Basic Principal of Tidal Power

Tides are produced mainly by the gravitational attraction of the moon and the sun on the water of solid earth and the oceans. About 70 per cent of the tide producing force is due to the moon and 30 per cent to the sun. The moon is thus the major factor in the tide formation. Surface water is pulled away from the earth on the side facing the moon, and at the same time the solid earth is pulled away from the water on the opposite side.

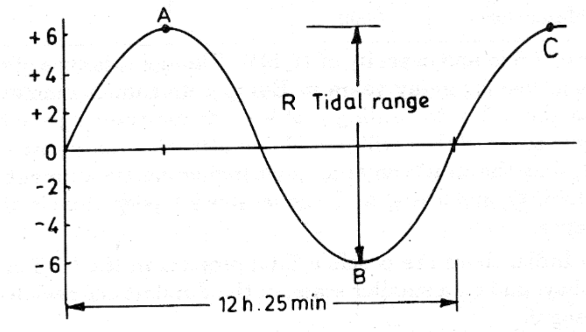


Fig. The tides of sea.

Thus high tides occur in these two areas with low tides at intermediate points. As the earth rotates, the position of a given area relative to the moon changes, and so also do the tides. There are thus a periodic succession of high and low tides. Although there are exceptions, two tidal cycles (i.e. two high tides and two low tides) occur during a lunar day of 24 hours and 50 minutes (The lunar day is the apparent time of revolution of the moon about the earth).

That is to say, the time between high tides and low tide at any given location is a little over 6 hours. A high tide will be experienced at a point which is directly under the moon. At the same time, a diametrically opposite point on the earth's surface also experiences a high tide due to dynamic balancing. Thus a full moon as well as a no moon produce a high tide. In a period of 24 hrs 50 minutes, there are therefore, two high tides and two low tides. These are called semi-diurnal tides. The rise and fall of the water level follows a sinusoidal curve, shown with point A indicating the high tide point and point B indicating the low tide point. The average time for the water level to fall from A to B and then rise to C is approximately 6 hours 12.5 mm.

The tidal range R is defmed as the difference between high and low water levels.

R = water elevation at high tide—water elevation at low tide.

Because of the changing positions of the moon and sun relative to the earth, the range varies continuously. There are however, some characteristic features of this variation.At times near full or new moon, when sun, moon and earth are approximately in a line, the gravitational forces of sun and moon enhance each other. The tidal range is then exceptionally large, the high tides are higher and low tides are lower than the average.

These high tides are called spring tides, on the other hand, near the first and third quarters of the moon, when the sun and moon are at right angles with respect to the earth, neap tides occur. The tidal range is then exception ally small; the high tides are lower and the low tides higher than the average. Hence the range is not constant. It varies during the 29.5 day lunar month being maximum at the time of new and full moons, called the spring tides, and minimum at the time of the first and third quarter moons, called the neap tides. The spring-neap tidal cycle lasts one-half of a lunar month. A typical mean range is roughly one third of the spring range. The actual variations in range are some what complicated by seasonal variations caused by the ellipticity of the earth's orbit around the sun.

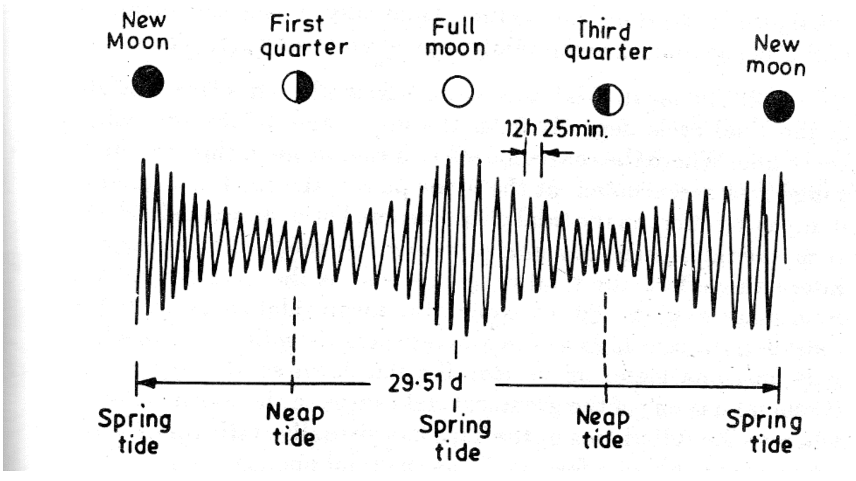


Fig. Relative high and low tides showing variation in range during lunar month.

The variations in the periodicity and monthly and seasonal ranges must, of course, by taken into account in the design and operation f tidal power plants. The tides, however, are usually predictable, and fairly accurate tide tables are usually available.

Tidal ranges vary from one earth location to another. They are influenced by such conditions as the profile of the local shoreline and water depth. When these are favourable, a resonance like effect causes ver large tidal ranges. Ranges have to be very large to justify the huge csts of building dams and associated hydroelectric power plants. Such les occur only fri a few locations in the world.

Following points have to be specially noted in connection with tidal phenomenon.

(1) The tides are a periodical phenomenon but no two tides in am- cycle are alike. Since the relative positions of sun and moon and their distances from earth are continuously changing, the tides are also influenced accordingly. Of the two high tides in a single day, one tide is higher than the other. In any month, the tides on the full moon and no moon days are particularly higher than the rest, as on these days sun's and moon's attraction acts in a directly additive manner. These are termed as the spring tides. In any year, the tides that occur at the time of versnal and autumnal equinoxes will we even higher due to the relative location of the sun and earth. Thus the tidal range R shown in the figure varies from time to time. Generally, a long time mean value of R is designated as mean tidal range at any particular place.

(2) The mean tidal range varies from place to place. The shape of the tidal cycle depends upon the interaction of the sea with the coast-line. Where the coast-line offers a resonating influence, the tidal range gets accentuated, at the other places, the land may produce a dampening effect on the tidal phenomenon. For instance, in land locked seas, the tidal phenomenon is always much subdued. Because of this interacting effect, the tidal range (as well as the tidal period) varies from place to place. For example ; the mean tidal range on the west coast of India is as high as 7 to 8 meters near the gulf of Kutch, whereas it is only one meter or so near Kerala, down south. Bay of Fundy (Canada) has one of the greatest tidal ranges in the world i.e. of 20 m, whereas the Adiaticsea at the Zara has virtually static water with the range being only of a few cm. Thus the tidal phenomenon is a unique feature of every coast line.

(3) in spite of their complexity, the tides are amenable to mathematical analysis. As a result the exact time and the water level for .i high tide as low tide can be forecast with great accuracy.

Advantages Of Tidal Power Plants

- Tidal power is predictable
- It is free from pollution
- Tidal power plants do not require valuable land as these are located on sea shores.
- Tidal power when used in a combination with a thermal plant can meet effectively the load demand.
- It is a renewable source of energy.

Disadvantages Of Tidal Power Plants

- Tidal power plant output varies with the variation in tidal range.
- Tidal power supply is intermittent.
- Capital cost of a tidal plant is not economical.
- Silting of basins is a problem with a tidal power plants

Site Selection For Tidal Power Plant

The suggested approach to the development of a tidal power scheme leading to the struction of a tidal power plant is as follows:

- ❖ Pre-feasibility study: Acquisition of data such as tides, local topography, infrastructure, etc. is the first requirement.
- ❖ Feasibility study: It comprises mathematical modelling, preliminary energy computation, foundation investigations, hydraulic model studies, detailed analysis of various modes of operation.
- ❖ Detailed design, preparation of specifications and tender documents.
- ❖ Construction of the plant.

Pre-feasibility Study

The following maps, charts, data and information about the scheme site need to be collected during the pre-feasibility study.

- ❖ Local land area map, survey of India map and hydrographic charts
- ❖ Historical data on tides and tidal currents
- ❖ Geotechnical properties of the sea bed and coastal region in the study area
- ❖ Typical weather conditions, rainfall wind and wave data
- ❖ Nearest high voltage substation for connecting the generated electric power with the state grid

9. **Types Of Tidal Power Plants/ Explain with neat sketch various method of tidal power generation (April/May 2012)(Nov 2012)**

Tidal power plants can be broadly classified into the following four categories:

1. Single-basin single-effect plant
2. Single-basin double-effect plant
3. Double-basin with linked-basin operation
4. Double-basin with paired-basin operation

10. Single-basin Single-effect Plant

It is the oldest form of tidal power development and the basis of many tide mills. A tidal power .is simply a barrage (dam or dyke) across an estuary or creek, whose principal elements are powerhouse and a sluice as shown in Figure below.

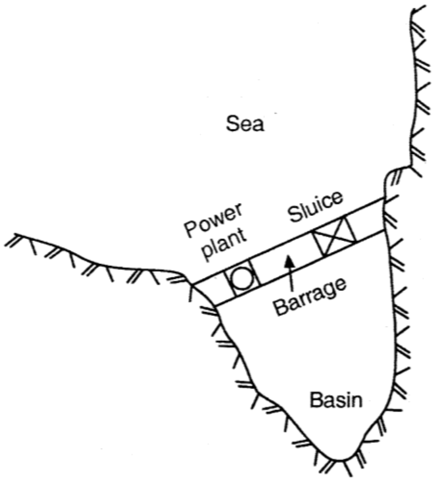


Figure Single-basin single-effect tidal plant.

The basin is filled through the sluice by the rising tide. The water level in the basin reaches the highest level of the tide. It provides the water head of tidal range to the turbine. The sluice gate is closed. The turbine is started only when the water in the sea is at falling tide level. As the tide continues to fall a hydraulic head is formed at the barrage and at an appropriate timewater is released from the basin through the generating unit installed in the powerhouse. Electric power generation continues until the head is reduced to the minimum turbine operating level. It normally occurs after the tide has reached its lowest point and has begun to rise again. At this stage the turbine water passage is closed and all discharge from the basin is stopped.

When the rising tide reaches the basin level, the filling sluice is opened, refilling of the basin starts and the cycle is repeated. The cycle of operation showing the water level, the generating and the refilling periods, is depicted in Figure below

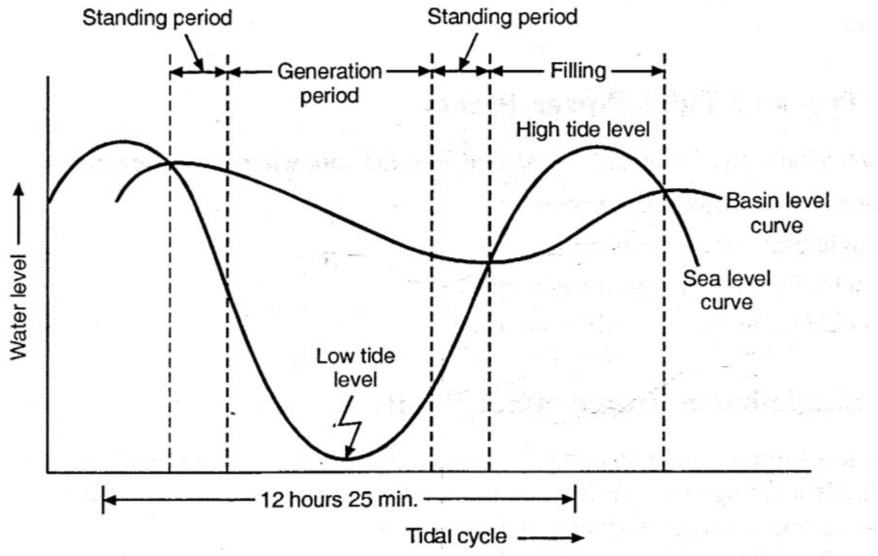


Figure: Operating cycle of single-basin single-effect plant.

The above cycle of operation offers different output characteristics depending on the time with respect to the tidal cycle at which generation starts and stops and on the turbine capacity. There are three variables which affect the power characteristics of ebb tide at a particular tidal site, namely:

1. The turbine capacity
2. Minimum head under which the turbine will operate efficiently
3. Time at which generation starts and stops.

These three variables need to be adjusted to produce the best possible results. In general the aim should be to get as long a period of operation as possible, and with this objective, the turbines would commence and stop operating at the minimum head consistent with high efficiency.

In a single-basin single-effect tidal plant with ebb tide operation, the generation period is only for 3.5 hours during every tide cycle. There are two tide cycles per day, so the energy available is intermittent and fluctuates from a maximum at spring tides to a minimum at neaps.

Single basin rising tide operation

The single basin flood tide operation is similar to ebb tide operation, with the difference that power generation during rising tide is less than that at ebb tide working. In rising tide, there is rapid filling of the basin, so the turbine operates for a reduced period. In ebb tide operation, the turbine and the generator operate for a longer time giving higher output. Thus, the single basin rising tide operation, besides its lower output, also suffers from intermittent and variable output.

Single-basin Double-effect Plant

This arrangement makes use of the combination of the ebb tide and the flood tide working, and power is generated both during emptying and filling of the basin. With a single barrage as shown in below Figures (a) and (b) the water head which produces the energy operates from the sea towards the basin during the flood tide and from the basin towards the sea during the ebb tide. The most practical method of achieving the double tide operation is by the

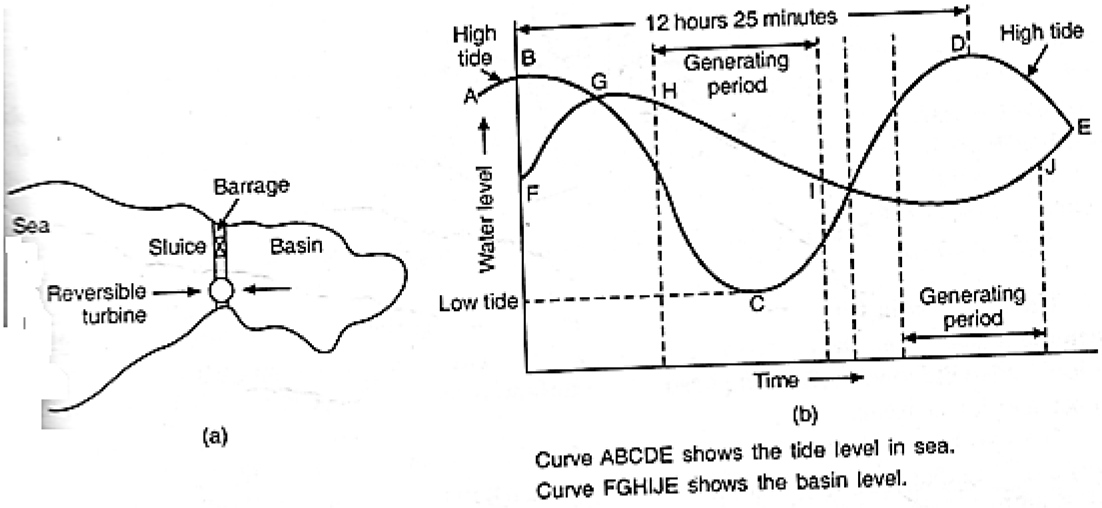


Figure: (a) Single basin with reversible turbine, and (b) single-basin double-effect power plant operating cycle.

Use of the reversible turbine which can operate in both directions of flow. In the operating cycle for double-effect operation, the curve shows that the output is variable and intermittent, but to a lesser extent than that in the case of the unidirectional flow power plant. Other advantages over the one-way plant are:

i. The overall output from an equal turbine capacity is greater by 15%. This percentage may increase if each plant is designed to the most economic type specification.
ii. The period of operation is increased.

The reversible turbines and other allied equipment cost a little more, this additional cost is offset by the above two advantages.

Due to its large period of operation, the operating regime of power generation can be manipulated so as to offer power to any predetermined period, either to suit the demand or to suit the tides. La Rance power plant of 240 MW in France is working on this type of operation.

11. Double-basin with Linked-basin Operation

It requires two separate but adjacent basins. In one basin called "upper basin" (or high pool), the water level is maintained above that in the other, the low basin (or low pool). Because there is always a head between upper and lower basins, electricity can be generated continuously, although at a variable rate.

In this system the turbines are located in between the two adjacent basins, while the sluice gates are as usual embodied in the dam across the mouths of the two estuaries. At the beginning of the flood tide, the turbines are shut down, the gates of upper basin A are opened and those of the lower basin B are closed. The basin A is thus filled up while the basin B remains empty. As soon as the rising water level in A provides sufficient difference of head between the two basins, the turbines are started.

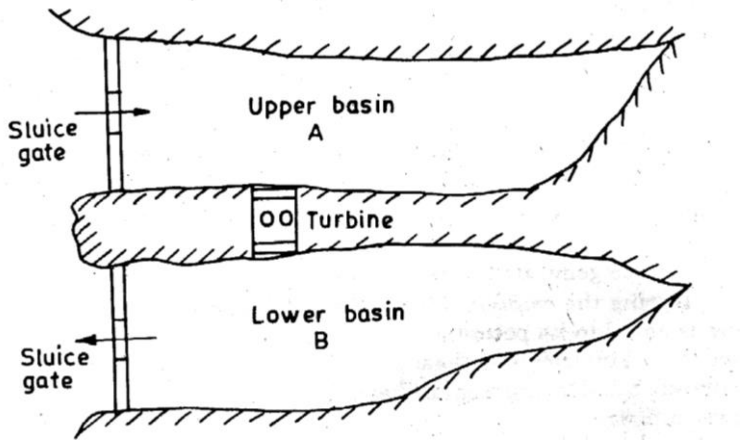


Fig: Tidal power plant Double Basin with Linked-basin Operation.

The water flows from A to B through the turbines, generating power. The power generation thus continues simultaneously with the filling up the basin A. At the end of the flood tide when A is full and the water level in it is the maximum, its sluice gates are closed. When the ebb tide level gets lower than the water level in B, its sluice gates are opened whereby the water level in B, which was arising and reducing the operating head, starts falling with the ebb. This continues until the head and water level in A is sufficient to run the turbines. With the next flood tide the cycle repeats itself. With this twin basin system, a longer and more continuous period of generation per day is possible. The small gaps in the operation of such stations can be filled up by thermal power.

The operation of the two basin scheme can be controlled so that there is a continuous water flow from upper to lower basin. However since the water head between the basins varies during each tidal cycle, as well as from day to day, so also does the power generated. As in the case with single basin scheme, the peak power generation does not often correspond in time with the peak demand. One way of improving the situation is to use off-peak power, from the tidal power generators or from an alternative system, to pump water from the low basin to the high basin. An increased head would then be available for tidal power generation at times of peak demand. This is very similar to pumped storage system in hydro-electric power stations.

The two-basin scheme may be economically viable where power demand is less than the guaranteed output as determined by the tide cycle. Alternatively, the two-basin system can be operated by retaining water in high basin and releasing it to meet peak demands only.

Double-basin with Paired-basin Operation

The paired basin scheme consists of two single-basin single-effect separate schemes located at a distance from each other. The locations are so selected that there is a difference in tidal phase between them. Both the schemes never exchange water, but are interconnected electrically. Both the basins operate in single-basin single-effect mode. One basin generates electrical energy during the ‘filling’ process while the other during the ‘emptying’ process. The scheme is shown in Figure below.

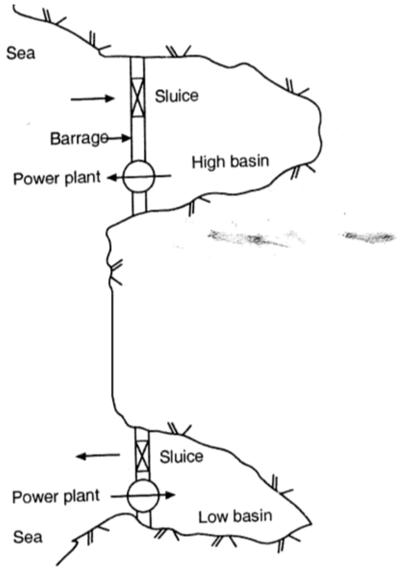


Figure :Double-basin with paired-basin operation.

This arrangement affords a little more flexibility in operation of the plants to meet power demands. More benefit can be derived if there is a difference in tidal phase of the sea near the two basins. In case where there is no difference in tidal phase, variations in power output can be evened out by resorting to ebb tide operation in one plant and flood tide operation in the other.

The paired-basin operation leads to a continuous output, still its power supply remains irregular and there is no solution for equalizing the great difference in output between the spring and the neap tide operaton. Further, it is difficult to find two tidal sites within reasonable distance of each other having the requisite difference in time of high water.

12. Tidal Energy In World Scenario

The La Rance tidal electric plant was built between 1961 and 1967 and energy production started in 1966. The estuary of the Rance is 3 km south of St. Malo, and is 750 m wide at the project site. The barrage consists of a ship lock, a powerhouse, and a short rockfill section. There is a 115 m long sluice structure with six fixed roller gates (15 m wide x 10 m high) capable of passing the flow, at mean tide, of 9600 m under a 5 m head.

The sluiceways allow complete emptying of the basin at the end of direct generation period or complete filling at the end of reverse generation. This happens when the difference in head between the basin and the sea is smaller than the minimum working head for driving the turbine, i.e. 1.2 m outwards when emptying the basin or 1.6 m inwards when filling. The sluice section is also used for total filling of the basin in the single-effect ebb-flow mode of operation. The generating units operate as orifices to assist the sluices.

The turbo-generator units are double regulated, reversible bulb turbines capable of turbining or pumping in both directions. Twenty-four machines are installed, each with 5.35 m diameter runner, directly coupled to a 10 MW generator-motor with a rated head of 6.65 m. The maximum head is 11 m and the minimum 3 m. Sectional elevations of the powerhouse, rockfilldyke and sluiceway are shown in Figure 11.17. The project is economically attractive when compared with the average cost of nuclear kWh and thermal kWh.

The average tide is 8.5 m and is of the semi-diurnal type. There is no seasonal effect throughout the year, but a two-week recurring cycle can be identified. It comprises nearly one week with spring tides between 9 m and 12 m, and one week with neap tides between 5 m and 9 m. The basin area is 22 sq. km. The following are the operational guidelines for this single- basin project.

1. For spring tides, i.e. tidal range greater than 11 m, double-effect generation is necessary because of the limited output of the machines.
2. For tides ranging between 7 m and 11 m, either reverse generation or direct pumping should be considered. In the former case there is more continuous supply of power but with loss of energy.
3. For neap tides, i.e. under 7 m, direct pumping can be more profitable, in terms of more quantity of energy.
4. Reverse pumping should be carried out with ranges over 11 metres.

13. Tidal Power Development In India

India has a long coastline of 6000 and there are promising sites for setting up tidal power plants in West Bengal and Gujarat. A feasibility report on tidal power prospect of Durgaduani Creek in Sunderbans area of West Bengal was carried out in 1995 jointly by National Institute of Ocean Technology Chennai and lIT Madras at the behest of the West Bengal Renewable Energy Development Agency. The mean tidal range is 3.54 m with a basin area of 1.07 sq. km. On the basis of the report, there is a proposal to install a 3 MW capacity tidal power plant in Durgaduani.

The main objective of the project is to provide electricity to the villages around Durgaduani Creek. It would improve the quality of life as the project shall be able to supply adequate power for agriculture development, installation of cold storage and refrigeration facilities for fish preservation, installation of pumps for fresh drinking water, development of industries and tourism in the area. In Sunderban area there is a potential of 50 MW of tidal power.

The Kalpasar reservoir will be 2000 sq. km. It will store three times the water in the Sardariovar reservoir.

The giant lake shall be harnessed for multipurpose activities such as:

- ❖ To generate 5380 MW of tidal power
- ❖ To provide 5.61 MCM of water annually to irrigate 10,54,500 ha of land of southern Saurashtra, where water is a scarce commodity
- ❖ To supply 900 MCM water for the industrial development of Saurashtra and Kutch
- ❖ To improve the existing ports like Ghogha and Bhavnagar due to the availability of higher water levels
- ❖ To breed fish in fresh water lake to generate extra income of about Rs 70 crores
- ❖ To reclaim saline land along the coast, about 1100 sq. 1cm, for cultivation

At present the project is on the drawing board; it will take 20 years to build with antimated cost of Rs. 50,000 crores. When constructed, the project will lead to a quantum jump in living standard of the people in the region. It has been suggested that a multilane highway and a railway can be built across the length of the dam which would slash the distance between South Gujarat and Mumbai by about 225 km.

- ❖ There are several positive factors about the execution of this project such as:
- ❖ No displacement of population from their homes
- ❖ Due to rising water levels there is a possibility to build more ports in the region
- ❖ The project is out of the threat of earthquake

It is a gigantic multipurpose project and will solve the state's water problems besides generating eco-friendly tidal power.

14. Economics Of Tidal Power

Tidal power, in its cheapest form can only be generated intermittently. To convert the intermittent low grade energy to guaranteed continuous energy, additional cost must be incurred. Another aspect is that due to the low generating heads, the cost of machinery and its supporting ructure is high.

The cost economy guides that a small-scale tidal power development must be justified on its own merits, so that the unit construction cost can definitely be offset against the other consequent benefits. Planning need not be aimed at the cheapest power production, but towards I the best beneifit-to-cost ratio of the project. The benefits can be numerous and some of them may be quite tangible.

There are some benefits other than the power benefit which can reduce the cost of energy to a competitive level. Major benefits that can accrue from tidal power are listed below:

- ❖ It is a renewable energy source free from weather vagaries. The cost of energy produced is quite nominal, i.e. only the operational cost.
- ❖ Performance of the plant is pollution free.
- ❖ Tidal power combined with the pumped storage generation ensures continuous powersupply.
- ❖ Road crossing on the barrage connects the isolated areas without constructing a bridge.
- ❖ It improves the transport and navigational facilities.
- ❖ Creates infrastructure for regional development.
- ❖ Recreational facilities generate tourism potential.
- ❖ Land reclamation of sea shore waste land is a long-term benefit.
- ❖ Social and political benefits are quite substantial.

15. Prospects Of Tidal Energy In India(Nov 2013)

The possible sites for tidal power generation in India are obviously those where high tidal ranges occur e.g. Gulf of Cambay (Bhavnagar Sonrai), Gulf of Kutch (Kandla, Navalakhi) and of Houghly river. The maximum tidal range in the Gulf of Cambay (10.8 m) and is attractive for a tidal plant.

There are two possible sites on the western bank namely, Sonrai creek and Bhavnagar creek which have the essential requirements for locating probable plants. However, the silt change of the Gulf of Cambay is about 5000 ppm which is thought to be high and needs a closer study for future development. Gulf of Kutch has a maximum spring tide range of 7.5 m.

The silt change here (near Navalakhi in the Gulf of Kutch) is much lower (nearly 1000 ppm). The tidal ranges and power potential of these sites are indicated in the table below. There is at present no indication regarding the cost of generation from tidal power. Preliminary studies already carried out by the CPWD and for tidal station in the Gulf of Cambay indicated higher cost of generation from conventional sources.

However, the cost of coal and other allied materials is increasing which may open up the possibility of exploitation of this source of power. Adequate data will have to be collected for any realistic assessment of tidal power potential and possible impact on the environment, current patterns, tidal reflections, sedimentation, erosion etc. Detailed feasibility reports based on full technology assessment are called for before venturing into this field.

Sites	**SpringTidalrange inmetres**	**Assumedarea in Sq.kms**	**TidalMaximum PotentialEnergy**	**SingleBasin CycleMW 10^8 kW/yr.**		**Two basins**			
						Alternatively operating MW108		**Cooperating MW108 kWh/yr.**	
Gulf of Kutch Navalakhi	7.5	10	1110	43	376	48	419	16.4	143
Gulf of Cambay	10.8	10	2300	89.4	784	100	880	34.2	300
Sagar	4.85	10	464	18	157	20.1	176	6.9	60
Diamond Harbour	3.9	10	686	26.6	233	29.7	262	10.15	89

16. Advantages And Limitations Of Tidal Power Generation

(1) The biggest advantage of the tidal power is besides being inexhaustible it is completely independent of the precipitation (rain) and its uncertainty. Even a continuous dry spell of any number of years can have no effect whatsoever on the tidal power generation.

(2) Tidal power generation is free from pollution, as it does not use any fuel and also does not produce any unhealthy waste like gases, ash, atomic refuse.

(3) These power plants do not demand large area of valuable land because they are on the bays (sea shore).

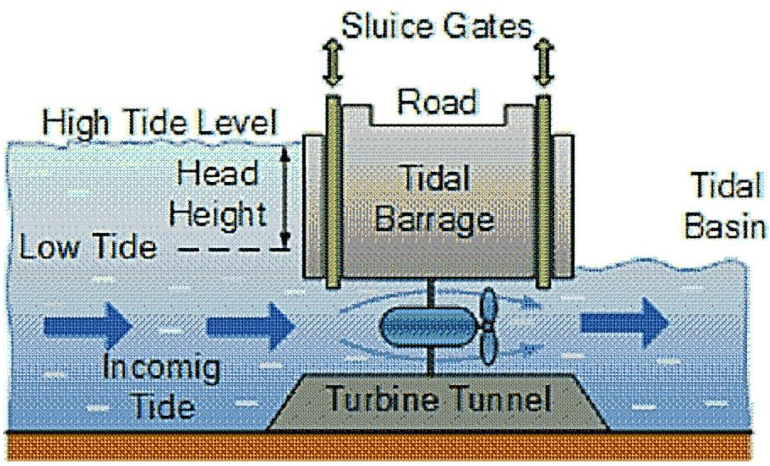
(4) Peak power demand can be effectively met when it works in combination with thermal or hydroelectric system.

17. Limitation of Tidal power plant

There are a number of reasons, why the tidal power generation is still a novelty, rather than a normal source of energy. The reasons can be enumerated as below:

(1) The fundamental drawback to all methods of generating tidal power is the variability in output caused by the variations in the tidal range.
(2) The tidal ranges are highly variable and thus the turbines have to work on a wide range of head variation. This affects the efficiency of the plant.
(3) Since the tidal power generation depends upon the level difference in the sea and an inland basin, it has to be an intermittent operation, feasible only at a certain stage of the tidal cycle. This intermittent pattern could be improved to some extent by using multiple basins and a double cycle system.
(4) The tidal range is limited to a few meters. Thus the bulb turbine technology was not well developed, use of conventional kaplan runners was the only alternative. This was found to be unsuitable. Now with the development of reversible flow bulb turbines, this difficulty isovercome.
(5) The duration of power cycle may be reasonably constant but its time of occurrence keeps in changing, introducing difficulties in the planning of the load sharing every day in a grid. This handicap can be removed now with the help of computerized programming.
(6) Sea water is corrosive and it was feared that the machinery may get corroded. Stainless steel with high chromium content and a small amount of molybdenum and the aluminium bronzes proved to be good corrosion resistant at La Rance project. The vinyl paint exhibited good results.
(7) Construction in sea or in estuaries is found difficult.
(8) Cost is not favourable compared to the other sources of energy.
(9) It is feared that the tidal power plant would hamper the other natural uses of estuaries such as fishing, or navigation.

18. Describe in briefly the component of tidal power plant (Nov 2013)



Tidal power is the power inherent in tides at sea or oceans that is the power of motion of water actuated by tides. Tides are defined as the increase and decrease in water levels due to the motion of water from one place to the other.

It is a fact that water level increase and decrease during the high and low tide of sea. Tidal barrage power generation system uses this method to produce the electricity.

Components Of Tidal Power Plant

The components of a tidal power station are as follow

A barrage

A barrage is a small wall built at the entrance of a gulf in order to trap water behind it. It is just like the dam structure. It will gather water by stopping it from going into the gulf when water levels at the sea are high or it will stop water from going into the sea when water level at the sea is low.

Turbines

Turbines are the components which convert the kinetic energy of water in to the rotational energy of the generator which convert rotational energy into electrical energy. They are located in the passageways that the water flows through when gates of barrage are opened

Sluices

Sluice gates are the ones responsible for the flow of water through the barrage

Embankments

They are caissons made out of concrete to prevent water from flowing at certain parts of the dam and to help maintenance work and electrical wiring to be connected or used to move equipment or cars over it

Working Phenomena

We have divided the working phenomena of tidal barrage generation into seven components

1 Tidal motion

As said above water level increase and decrease during the high and low tide of sea and this is the most important in this power generation system because it all depends upon the increasing and decreasing level of water

2 Barrage

Barrage is the wall structure just like the dam structure. Its function is to stop the water on one side during high tide and release it when it reach its maximum value and store it on other side and release it during low tide

3 Potential energy

I tidal barrage power generation system main source of energy is potential energy of water stored at some high due to the barrage. This energy will be converted to kinetic and then to electrical energy

4 Opening of barrage doors

Barrage store water during the high tide and when it reached its maximum value doors of barrage are open to let the water flow to the other side

5 Kinetic energy

As water when stored at some height has some potential energy and when doors are of water atsrt to flow to other side and potential energy is converted in to kinetic energy which will be used to produce the electrical energy

6 Using turbines

Up to now potential energy of water is converted into kinetic energy and now this kinetic energy will be converted into the rotational energy of turbine blades when they strike them. Blades attached to a shaft and the shaft is attached to the generator

7 Electrical energy

Water rotate blades which rotates the shaft and shaft rotates the generator which will produce the electrical energy and one cycle is completed. This process will be continuous till there is difference in the water level

Advantages of Tidal Power Generation

There are many advantages of generating power from the tide; some of them are listed below:

- Tidal power is a sustainable energy resource.
- It reduces fossil fuels dependence.
- It has very less visual impact.
- Construction of large-scale offshore devices results in new areas of sheltered water, attractive for fish, sea birds, seals and seaweed.
- Tidal energy is available worldwide on a large scale from deep ocean waters.
- Tidally driven coastal currents provide an energy density four times greater than air
- A feature which gives them an advantage over both wind and solar systems is that the tidal currents are both predictable and reliable
- Seawater is 832 times as dense as air; therefore the kinetic energy available is much greater than air

Disadvantages of Tidal Power Generation

- Unfortunately, there are also disadvantages and limitations to generating tidal power. Some of these are:
- At the present time there is a problem that the method is not economical.
- Tidal power systems do not generate electricity at a steady rate and thus not necessarily at times of peak demand
- Tidal fences could present some difficulty to migrating fish.

PONDICHERRY UNIVERSITY QUESTIONS

2 MARKS

1. What are the limitations of tidal energy power plant?(Nov 2012)
2. What are the types of tidal power plants?(April/May 2012)
3. Draw the double basin arrangement of tidal power plant (Nov 2013)

11 MARKS

1. Types Of Tidal Power Plants/ Explain with neat sketch various method of tidal power generation (April/May 2012)(Nov 2012)
2. Prospects Of Tidal Energy In India(Nov 2013)
3. Describe in briefly the component of tidal power plant (Nov 2013)

UNIT V: BIO-ENERGY

Energy from Bio- mass- Bio gas plants various types- Industrial wastes- Municipal waste- Burning plants –Energy from the Agricultural wastes Applications

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2- MARKS

1. **What is meant by biomass energy and biomass energy resource?**

   Organic matters derived from biological organisms are called Biomass. The energy obtained from biomass is called biomass energy. The raw organic matter obtained from nature for extracting secondary energy is called biomass energy resource.

2. **Classify the biomass resources.**
   Biomass resources are broadly classified into two categories:
   i. Biomass from cultivated fields, crop, forest and harvested periodically.

   ii. Biomass derived from waste e.g., municipal waste, animal excreta/dung, forest waste, agricultural waste, bioprocess waste, but charry waste, fishery waste/processing waste etc.,
3. **What do you mean by fossil fuels?**
   Fossil fuels (coal, petroleum oil and natural gases) are produced from dead, buried biomass under pressure and in absence of air during several millions of years. However; they are considered separately as fossils and are not included in the category of biomass.

4. **What are the categories of scope of biomass energy?**
   The scope of biomass energy is of three categories. They are
   a. Rural application of biomass energy
   b. Urban and industrial applications of biomass energy

c. Biomass as a primary source for large scale electrical power generation.

5. **List the secondary energy forms of biomass.**

The biomass can be converted to useful secondary energy forms such as

a. Heat
b. Gaseous fuels
c. Solid fuels
d. Organic chemical
e. Liquid fuels

6. **Point out the cultivated biomass.**

The cultivated biomass (biomass from energy farms) includes:

a. Sugar cane crops, sweet sorghum crops, sugar beets.
b. Herbaceous crops which are non-woody plants which can be converted into biogas or biochemical fuels.
c. Cereals, potatoes and other carbohydrate fruit crops, etc. grown for producing in feeds to the fermentation plants.
d. Forests crops of fast growing energy intensive trees specially grown as source of energy.
e. Aquatic crops grown in fresh water, sea water, muddy water etc., and these crops include submerged plants, surface plants and include sea weeds, marine algae, water hyacinth, floating kelp etc. algae is considered to be a promising aquatic biomass.

7. **List out the biomass energy resources from waste.**

The waste to energy processes convert organic wastes to intermediate or secondary energy forms such as heat, biogas, alcohol, fuels, chemicals, etc. The waste is classified as

a. Urban (municipal) waste
b. Industrial organic waste, process waste
c. Agricultural farm waste
d. Rural animal waste
e. Forest waste
f. Fishery, poultry, butcharry waste
g. Animal and human excreta

8. **What is meant by biogas plant?**

The plant which converts biomass to biogas (methane plus carbon dioxide) by the process of anaerobic digestion is generally called a biogas plant.

9. **Mention advantages of biomass energy**

a. It is a renewable source.
b. The energy storage is an in-built feature of it.
c. It is an indigenous source requiring little or no foreign exchange.
d. The forestry and agricultural industries that supply feed stocks also provide substantial economic development opportunities in rural areas.
e. The pollutant emissions from combustion of biomass are usually lower than those from fossil fuels.

10. **Mention disadvantages of biomass energy**

a. It is a dispersed and land intensive source.
b. It is often of low energy density.

c. It is also labour intensive and the cost of collecting large quantities for commercial application is significant. Most current commercial large quantities for commercial application are significant. Most current commercial applications of biomass energy, use material that has been collected for other reasons, such as timber and food processing residues and urban waste.
d. Capacity is determines by availability of biomass and not suitable for varying loads.
e. Not feasible to set up at all locations.

11. What is meant by biomass gasification?(Nov 2012)

The word gasification (or thermal gasification) implies converting solid fuel into a gaseous fuel by thermo chemical method without leaving any solid carbonaceous residue.

12. . Classify the biogas plant.

a. The biogas plant are classified into
b. Continuous and batch types
c. The dome and drum types

13. List the factors affecting bio digestion or generation of gas.(Nov 2013)

The factors affecting bio digestion or generation of gas are:

a. pH or the hydrogen-ion concentration
b. Temperature
c. Total sold content of the feed material
d. Loading rate
e. Seeding
f. Uniform feeding
g. Nutrients
h. Type of feed stocks
i. Toxicity due end product
j. Pressure
k. Acid accumulation inside the digester

14. Why the biogases are mainly utilized?

Biogases are mainly utilized.

a. The biogas can be utilized effectively for
b. Household cooking,
c. Lighting,
d. Operating small engines,
e. Utilizing power for pumping water,
f. Chaffing fodder
g. Grinding flour.

15. List the Feature of continuous plant

a. It will produce gas continuously.
b. It requires small digestion chambers.
c. It needs lesser period for digestion.
d. It has less problems compared to batch type and it is easier in operation.

16. List the Features of batch plant.

a. The gas production in it is intermittent, depending upon the clearing of the digester.

b. It needs several digesters or chambers for continuous gas production, these are fed alternatively.
c. Batch plants are good for long fibrous materials
d. This plant needs addition of fementated slurry to start the digestion process.
e. This plant is expensive and has problems comparatively; the continuous plant will have less problems and will be easy for operation.

17. Write the advantages of floating drum plant.

a. It has scum troubles because solids are constantly submerged
b. In it, the danger of mixing oxygen with the gas to form an explosive mixture is minimized
c. No problem of gas leakage
d. No problem of gas leakage

18. Write the disadvantages of floating drum plant.

a. It has higher cost, as cost is dependent on steel and cement.
b. Heat is lost through the metal gas holder, hence it troubles in colder regions and periods
c. Gas holder requires painting once or twice a year, depending on the humidity of the location.
d. Flexible pipe joining the gas holder to the main gas pipe requires maintenance, as it is damaged by ultraviolet rays in the sun. It may be twisted also, with the rotation of the drum for mixing or scum removal.

19. Mention some advantages of fixed dome type plant

a. This type of plant needs the service of skilled masons, who are rather scarce in rural areas.
b. Gas production per cum of the digester volume is also less.
c. Scum formation is a problem as no stirring arrangement.
d. It has variable gas pressure

20. What are the techniques or methods of maintaining biogas production?

The methods for maintaining biogas production are

a. Insulating the gas plant
b. Composting
c. Hot water circulation
d. Use of chemicals
e. Solar energy systems

21. What is meant by cogeneration?

A procedure for generating electric power and useful heat in a single installation is known as cogeneration. Heat may be supplied in the form of steam, hot water or hot air. The net result is overall increase in the efficiency of fuel utilization.

22. Mention the types and explain the cogeneration principles.

Types of cogeneration principles are:

The Topping Cycle:

Primary heat is used to generate high pressure and temperature steam for electrical energy generation. The discharged low grade heat, which would otherwise be dispersed to the environment, is utilized in an industrial process or in other ways.

The Bottoming Cycle:

Primary heat at high temperature is used directly for industrial process requirements. The remaining low grade heat is then used for electrical power generation, e.g. high temperature cement kiln.

23. Three general types of cogeneration systems

The three general types of cogeneration principles systems are:

a. Waste heat utilization
   - **i.** space heating and cooling
   - **ii.** warm water in agriculture
   - **iii.** warm water in aquaculture

b. Total/Integrated energy system for residential complex

c. Total energy system (TES) for industry.

24. What is meant by incineration?

Organic matter can be burnt in presence of oxygen/air to produce heat and by products. This is the well known process called combustion. Complete combustion to ashes is called incineration.

25. What are the types of Gasifiers?

a. In down draft gasifier fuel and air move in a co current manner

b. In update gasifier fuel and air move in a counter current manner. But the basic reaction zones remain the same.

26. What are the types of biomass resources?

a. Forests

b. Agricultural crops residues

c. Energy crops

d. Vegetable oil crops

e. A quatic crop

f. Animal waste

g. Urban waste

h. Industrial waste

27. What is Trans estarification?

Process where the raw vegetable oils are treated with alcohol (Methanol or ethanol with a catalyst) to form methyl or ethyl esters.

28. What are the advantages of bio-diesel as engine fuel?

a. Biodegradable produces 80% less and co2 100% less So2 emissions

b. Renewable
c. Higher octane number
d. Can be used as neat fuel or mixed in any ratio with petrol diesel
e. Has a higher flash point making it safe to transport

29. What are the components of cogeneration system?

a. Prime mover
b. Generator
c. Heat recovery
d. Electrical interconnection
e. Configured in to an integrated whose

30. What are the types of prime movers?

a. Reciprocating engine
b. Combustion of gas functions
c. Steam turbines
d. Micro turbines
e. Fuel cells

31. Write any two benefits of cogeneration

a. Increased efficiency of energy conversion and use
b. Lower emission to the environment in particular of co2, the main green house gas
c. Biomass fuels and some waste materials such as refinery gases, agricultural wastes are used. They serve as fuels for cogeneration schemes increases the cost effectiveness and reduces the need for waste disposal

32. What are the types of cogeneration system?

a. Steam turbine cogeneration system
b. Gas turbine cogeneration system
c. Reciprocating engine cogeneration system

33. What are the types of steam turbine?

a. Back pressure turbine
b. Extraction condensing turbine

34. How bio gas is produced (Nov 2013)

The bio gas is produced by the following two processes

a. Aerobic digestion.
b. Anaerobic digestion.15

The digestion process occurring in presence of Oxygen is called Aerobic digestion and produces mixtures of gases having carbon dioxide (CO2), one of the main green houses responsible for global warming.

The digestion process occurring without (absence) oxygen is called Anaerobic digestion which generates mixtures of gases. The gas produced which is mainly methane produces 5200-5800 KJ/m3 which when burned at normal room temperature and presents a viable environmentally friendly energy source to replace fossil fuels (non-renewable)

35. What are the constituents of bio gas (April/May 2012)

Typical composition of biogas

Compound	Formula	%
Methane	CH_4	50–75
Carbon dioxide	CO_2	25–50
Nitrogen	N_2	0–10
Hydrogen	H_2	0–1

36. Classification of biogas plant (April/May 2012)

- Fixed dome plant
- Floating drum plant
- Plastic covered plant

11 Marks

1. Principles For Production Of Biogas/ how bio mass conversion takes place (Nov 2012)

Organic substances exist in wide variety from living beings to dead organisms . Organic matters are composed of Carbon (C), combined with elements such as Hydrogen (H), Oxygen (O), Nitrogen (N), Sulphur (S) to form variety of organic compounds such as carbohydrates, proteins & lipids. In nature MOs (micro organisms), through digestion process breaks the complex carbon into smaller substances.

There are 2 types of digestion process:

i. Aerobic digestion.
ii. Anaerobic digestion

The digestion process occurring in presence of Oxygen is called Aerobic digestion and produces mixtures of gases having carbon dioxide (CO2), one of the main green houses responsible for global warming.

The digestion process occurring without (absence) oxygen is called Anaerobic digestion which generates mixtures of gases. The gas produced which is mainly methane produces 5200-5800 KJ/m3 which when burned at normal room temperature and presents a viable environmentally friendly energy source to replace fossil fuels (non-renewable)

Physical Processes / Mechanical Methods

This method is used to increase the bulk density of biomass material for easy transportation and storage and involves the following processes.

1.Briquetting: The briquetting is the process of making small size compressed block to get more surface area per unit weight of biomass by adding suitable binder. It includes the following process.

a. Moisture removal: The process involves the removal of moisture from contents to break down its elasticity to reduce its volume sufficiently.

b. Densification: The product is carried out at high pressure and temperature 180^0C to get more homogeneous product after moisture is removed.

2.Pelletization: Fuel pellets or refused derived fuel (RDF) are small cubes mode from the solid waste/garbage and are used as a fuel for boilers to produce steam or electricity. Pelletization of the wood is carried out by compressing it in the forms of rods of small diameter 5-12 mm in the extruder after removal of moisture 7-10%.

3.Size Reduction: Making small pieces by using shredding machines or Hammer mills.

Different types of dry processes

1. **Combustion:** Direct combustion is a complete oxidation process where liberation of heat is the primary objective. Burning of any substance in excess air whether it be solid, liquid or gas is termed as combustion. In combustion, a fuel is oxidized evolving heat and often light

$$C+O_2 \longrightarrow CO_2 + \text{Heat}$$

The combustion of solid fuel occurs in stages. i.e. Actual combustion of organic residues is not a single process but a combination of processes occurring simultaneously.

Three overlapping phases can be identified as

1. Initial phase: Evaporation of moisture
2. Volatilization and burning of volatiles: Dry matter absorbs heat, drives off volatile gases by thermal decomposition of the fuel and burning of volatiles in the air occurs.
3. Final phase: Fixed carbon burns

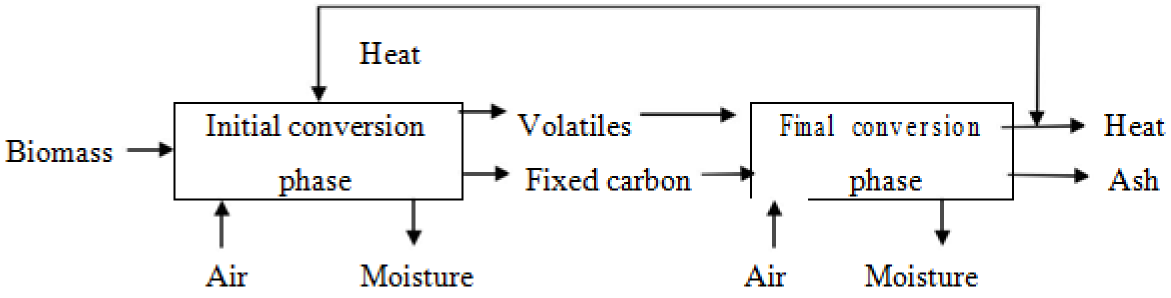


Fig: Schematic of the direct combustion process

At usual combustion temperature, the burning of hot solid residue is controlled by rate at which oxygen of the air diffuses to its surface. If the residue is cooled by the radiation of heat, combustion ceases.

Eg: Open chulas thermal efficiency : 3 – 4 % Improved chulas thermal efficiency :10 – 14%

Consumption of the fuel : 0.5 – 1 Kg /per person Use: To produce steam for process use and for electricity

2. Pyrolysis: Pyrolysis is defined as the destructive distillation of organic material heated to more than 200^{0}C in the absence of air/oxygen for several hours to produce combustible gases (H_2, CO, CH_4), other hydrocarbons, CO_2 and N_2, solid char, liquid tar and organic liquids. It is a non oxidative thermal process that results in gases, liquids and char. It is thermal degradation of cellulose. In practice, many processes allow a restricted admission of air for partial combustion to achieve the temperature required for pyrolysis. The temperature of pyrolysis, composition of biomass (C, H, N, O, S), retention period and heating rate in pyrolyser etc determine the nature and quantum of these products. The slow rate of heating, low temperature and adequate retention time tend to give high yields of char.

Uses of pyrolytic products

Product	Char	Liquids	Gases
Uses	1. Domestic Fuel 2. Industrial Fuel 3. Metturgical Fuel 4. Chemical feed stock for calcium carbide, silicon carbide etc.	1. Fuel 2. Separation for phenol and other chemicals 3. Germicide 4. Wood preservative	1. Industrial fuel 2. Fuel for IC engines for mechanical and electrical power

3. **Gasification**: It is a chemical change involve several chemical reactions which occur simultaneously at varying rates. The dry process is combustion of biomass in a controlled atmosphere. This is a gasification process involving the burning of biomass with a limited air supply at temperature above 1100^0C. The typical product is a mixture of $CO+H_2$ i.e. producer gas which is $1/10^{th}$ of the petroleum gas.

   Useful for cooking, heating and electricity generation.

4. **Liquification:** The dry process of biomass conversion is hydro carbonization or liquification which combines high temperature and pressure to produce oil or gas. These Fuels are same as that of petroleum and natural gas. But the operating cost and energy expenditure higher than pyrolysis.

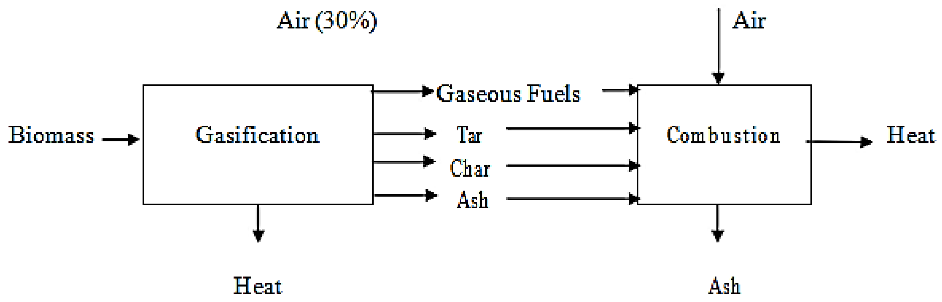


Fig: Schematic showing the gasification process

2. Different category of Bio Mass

Biofuel:

A biofuel is a type of fuel whose energy is derived from biological carbon fixation. Biofuels include fuels derived from biomass conversion, as well as solid biomass, liquid fuels and various biogases. Biofuels are gaining increased public and scientific attention, driven by factors such as oil price hikes and the need for increased energy security. However, according to the European Environment Agency, biofuels do not address global warming concerns.

Bioethanol is an alcohol made by fermentation, mostly from carbohydrates produced in sugar or starch crops such as corn or sugarcane. Cellulosic biomass, derived from non-food sources, such as trees and grasses, is also being developed as a feedstock for ethanol production. Ethanol can be used as a fuel for vehicles in its pure form, but it is usually used as a gasoline additive to increase octane and improve vehicle emissions. Bioethanol is widely used in the USA and in Brazil. Current plant design does not provide for converting the lignin portion of plant raw materials to fuel components by fermentation.

Biodiesel is made from vegetable oils and animal fats. Biodiesel can be used as a fuel for vehicles in its pure form, but it is usually used as a diesel additive to reduce levels of particulates, carbon monoxide, and hydrocarbons from diesel-powered vehicles. Biodiesel is produced from oils or fats using transesterification and is the most common biofuel in Europe.

In 2010, worldwide biofuel production reached 105 billion liters (28 billion gallons US), up 17% from 2009,and biofuels provided 2.7% of the world's fuels for road transport, a contribution largely made up of ethanol and biodiesel.[citation needed] Global ethanol fuel production reached 86 billion liters (23 billion gallons US) in 2010, with the United States and Brazil as the world's top producers, accounting together for 90% of global production. The world's largest biodiesel producer is the European Union, accounting for 53% of all biodiesel production in 2010.[3] As of 2011, mandates for blending biofuels exist in 31 countries at the national level and in 29 states or provinces. According to the International Energy Agency, biofuels have the potential to meet more than a quarter of world demand for transportation fuels by 2050.

Bioalcohols:

Biologically produced alcohols, most commonly ethanol, and less commonly propanol and butanol, are produced by the action of micro organisms and enzymes through the fermentation of sugars or starches (easiest), or cellulose (which is more difficult). Biobutanol (also called bio-gasoline) is often claimed to provide a direct replacement for gasoline, because it can be used directly in a gasoline engine (in a similar way to biodiesel in diesel engines).

Ethanol fuel is the most common biofuel worldwide, particularly in Brazil. Alcohol fuels are produced by fermentation of sugars derived from wheat, corn, sugar beets, sugar cane, molasses and any sugar or starch from which alcoholic beverages can be made (such as potato and fruit waste, etc.). The ethanol production methods used are enzyme digestion (to release sugars from stored starches), fermentation of the sugars, distillation and drying. The distillation process requires significant energy input for heat (often unsustainable natural gas fossil fuel, but cellulosic biomass such as bagasse, the waste left after sugar cane is pressed to extract its juice, can also be used more sustainable).

Ethanol can be used in petrol engines as a replacement for gasoline; it can be mixed with gasoline to any percentage. Most existing car petrol engines can run on blends of up to 15% bioethanol with petroleum/gasoline. Ethanol has a smaller energy density than that of gasoline; this means it takes more fuel (volume and mass) to produce the same amount of work. An advantage of ethanol (CH3CH2OH) is that it has a higher octane rating than ethanol-free gasoline available at roadside gas stations, which allows an increase of an engine's compression ratio for increased thermal efficiency. In high-altitude (thin air) locations, some states mandate a mix of gasoline and ethanol as a winter oxidizer to reduce atmospheric pollution emissions.

Ethanol is also used to fuel bioethanol fireplaces. As they do not require a chimney and are "flueless", bioethanol fires are extremely useful for newly built homes and apartments without a flue. The downside to these fireplaces is their heat output is slightly less than electric heat or gas fires.

In the current corn-to-ethanol production model in the United States, considering the total energy consumed by farm equipment, cultivation, planting, fertilizers, pesticides, herbicides, and fungicides made from petroleum, irrigation systems, harvesting, transport of feedstock to processing plants, fermentation, distillation, drying, transport to fuel terminals and retail pumps, and lower ethanol fuel energy content, the net energy content value added and delivered to consumers is very small. And, the net benefit (all things considered) does little to reduce imported oil and fossil fuels required to produce the ethanol.

Although corn-to-ethanol and other food stocks have implications both in terms of world food prices and limited, yet positive, energy yield (in terms of energy delivered to customer/fossil fuels used), the technology has led to the development of cellulosic ethanol. According to a joint research agenda conducted through the US Department of Energy,[8] the fossil energy ratios (FER) for cellulosic ethanol, corn ethanol, and gasoline are 10.3, 1.36, and 0.81, respectively.

Even dry ethanol has roughly one-third lower energy content per unit of volume compared to gasoline, so larger (therefore heavier) fuel tanks are required to travel the same distance, or more fuel stops are required. With large current unsustainable, unscalable subsidies, ethanol fuel still costs much more per distance traveled than current high gasoline prices in the United States.

Methanol is currently produced from natural gas, a nonrenewable fossil fuel. It can also be produced from biomass as biomethanol. The methanol economy is an alternative to the hydrogen economy, compared to today's hydrogen production from natural gas.

Butanol (C4H9OH) is formed by ABE fermentation (acetone, butanol, ethanol) and experimental modifications of the process show potentially high net energy gains with butanol as the only liquid product. Butanol will produce more energy and allegedly can be burned "straight" in existing gasoline engines (without modification to the engine or car), and is less corrosive and less water-soluble than ethanol, and could be distributed via existing infrastructures. DuPont and BP are working together to help develop butanol. E.

coli strains have also been successfully engineered to produce butanol by hijacking their amino acid metabolism.

Biogas:

Biogas is methane produced by the process of anaerobic digestion of organic material by anaerobes. It can be produced either from biodegradable waste materials or by the use of energy crops fed into anaerobic digesters to supplement gas yields. The solid byproduct, digestate, can be used as a biofuel or a fertilizer.

Biogas can be recovered from mechanical biological treatment waste processing systems. Note: Landfill gas, a less clean form of biogas, is produced in landfills through naturally occurring anaerobic digestion. If it escapes into the atmosphere, it is a potential greenhouse gas. Farmers can produce biogas from manure from their cattle by using anaerobic digesters

3. List the Factors affecting the biogas production

- Substrate temperature
- pH level
- Mixing Ratio
- Loading Rate
- Hydraulic Retention time
- Nitrogen inhibition
- C/N ratio
- Agitation
- Toxicity
- Solid concentration
- Seeding
- Metal Cations
- Particle size
- Additives
- BOD
- COD
- Heating

4. Benefits Of Biogas Technology :

a. Production of energy.
b. Transformation of organic wastes to very high quality fertilizer.
c. Improvement of hygienic conditions through reduction of pathogens.
d. Environmental advantages through protection of soil, water, air etc. Micro-economical benefits by energy and fertilizer substitutes. Macro-economical benefits through decentralizes energy generation and environmental protection.

5. Explain in details about various types of Biogas power plant (Nov 2012)(Nov 2013)

Main types of simple biogas plants:

- ❖ Balloon plants,
- ❖ Fixed-dome plants,
- ❖ Floating-drum plants.

Balloon Plants

A balloon plant consists of a plastic or rubber digester bag, in the upper part of which the gas is stored. The inlet and outlet are attached direct to the skin of the balloon. When the gas space is full, the plant works like a fixed-dome plant - i.e., the balloon is not inflated; it is not very elastic. The fermentation slurry is agitated slightly by the movement of the balloon skin. This is favourable to the digestion process. Even difficult feed materials, such as water hyacinths, can be used in a balloon plant. The balloon material must be UV-resistant. Materials which have been used successfully include RMP (red mud plastic), Trevira and butyl.

Advantages:

- ❖ Low cost,
- ❖ ease of transportation,
- ❖ low construction (important if the water table is high),
- ❖ high digester temperatures, uncomplicated cleaning,
- ❖ Emptying and maintenance.

Disadvantages:

- ❖ Short life (about five years),
- ❖ easily damaged,
- ❖ does not create employment locally,
- ❖ little scope for self-help.

Balloon plants can be recommended wherever the balloon skin is not likely to be damaged and where the temperature is even and high. One variant of the balloon plant is the channel-type digester with folia and sunshade

Fixed-Dome Plants:

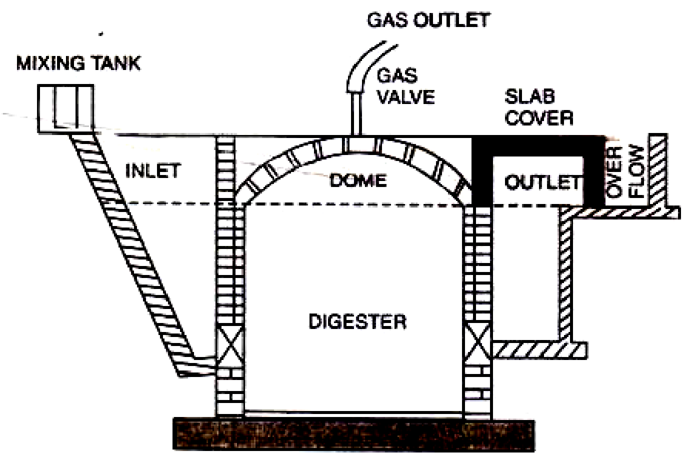


FIG. 4.3 : FIXED DOME TYPE BIOGAS PLANT

A fixed-dome plant consists of an enclosed digester with a fixed, non-movable gas space. The gas is stored in the upper part of the digester. When gas production commences, the slurry is displaced into the compensating tank. Gas pressure increases with the volume of gas stored; therefore the volume of the digester should not exceed 20 m³. If there is little gas in the holder, the gas pressure is low.

Floating-Drum Plants:

Floating-drum plants consist of a digester and a moving gasholder. The gasholder floats either direct on the fermentation slurry or in a water jacket of its own. The gas collects in the gas drum, which thereby rises. If gas is drawn off, it falls again. The gas drum is prevented from tilting by a guide frame.

Advantages:

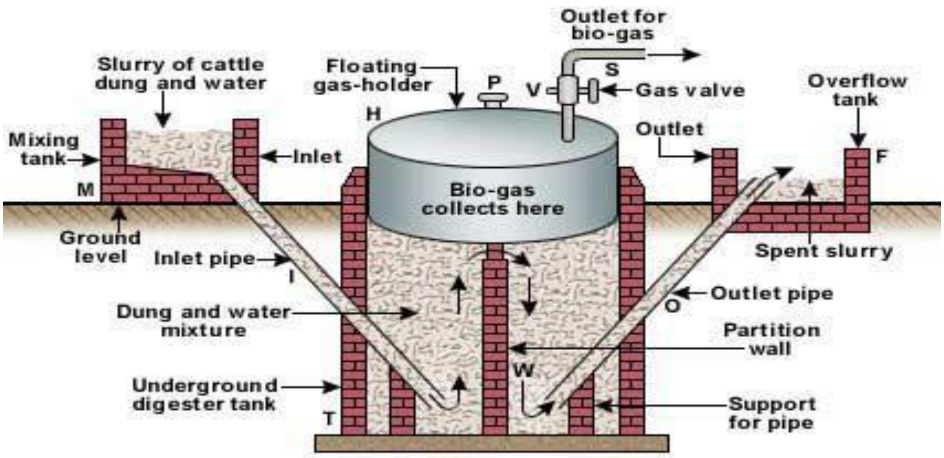
- Simple,
- easily understood operation,
- constant gas pressure,
- volume of stored gas visible directly,
- few mistakes in construction.

Disadvantages:

- High construction cost of floating-drum,
- many steel parts liable to corrosion,
- resulting in short life (up to 15 years; in tropical coastal regions about five years for the drum),
- regular maintenance costs due to painting.

In spite of these disadvantages, floating-drum plants are always to be recommended in cases of doubt. Water-jacket plants are universally applicable and especially easy to maintain. The drum won't stick, even if the substrate has high solids content.

Floating-drums made of glass-fibre reinforced plastic and high density polyethylene have been used successfully, but the construction cost is higher than with steel. Floating-drums made of wire-mesh-reinforced concrete are liable to hairline cracking and are intrinsically porous. They require a gaslight, elastic internal coating. PVC drums are unsuitable because not resistant to UV.



Floating gas-holder type bio-gas plant.

The floating gas drum can be replaced by a balloon above the digester. This reduces construction costs (channel type digester with folia), but in practice problems always arise with the attachment of the balloon at the edge. Such plants are still being tested under practical conditions.

6. Energy from biomass:

1. Alternative source of energy
2. We have plenty of agricultural and forests for production of biomass.
3. Produced through photosynthesis achieved by solar energy conversion
4. Biomass means organic matter (Carbohydrate)
5. $H_20 + CO_2$ -------------------> $CH_2O + O_2$
6. $CH_2O + O_2$ ---------------> $CO_2 + H_2O$+112 Kcal/mole
7. Algae has lots of carbohydrates, could be harvested, dried and burned for production of heat 8.thatcould be converted into electricity.
8. Can be converted into liquid and gaseous fuels.

7. Write briefly about Photosynthesis:(Nov 2013)

Photosynthesis is the process of converting light energy to chemical energy and storing it in the bonds of sugar. This process occurs in plants and some algae (Kingdom Protista). Plants need only light energy, CO2, and H2O to make sugar. The process of photosynthesis takes place in the chloroplasts, specifically using chlorophyll, the green pigment involved in photosynthesis.

Photosynthesis takes place primarily in plant leaves, and little to none occurs in stems, etc. The parts of a typical leaf include the upper and lower epidermis, the mesophyll, the vascular bundle(s) (veins), and the stomates. The upper and lower epidermal cells do not have chloroplasts, thus photosynthesis does not occur there. They serve primarily as protection for the rest of the leaf. The stomates are holes which occur primarily in the lower epidermis and are for air exchange: they let CO2 in and O2 out. The vascular bundles or veins in a leaf are part of the plant's transportation system, moving water and nutrients around the plant as needed. The mesophyll cells have chloroplasts and this is where photosynthesis occurs.

As you hopefully recall, the parts of a chloroplast include the outer and inner membranes, intermembranous space, stroma, and thylakoids stacked in grana. The chlorophyll is built into the membranes of the thylakoids.

Chlorophyll looks green because it absorbs red and blue light, making these colors unavailable to be seen by our eyes. It is the green light which is NOT absorbed that finally reaches our eyes, making chlorophyll appear green. However, it is the energy from the red and blue light that are absorbed that is, thereby, able to be used to do photosynthesis. The green light we can see is not/cannot be absorbed by the plant, and thus cannot be used to do photosynthesis.

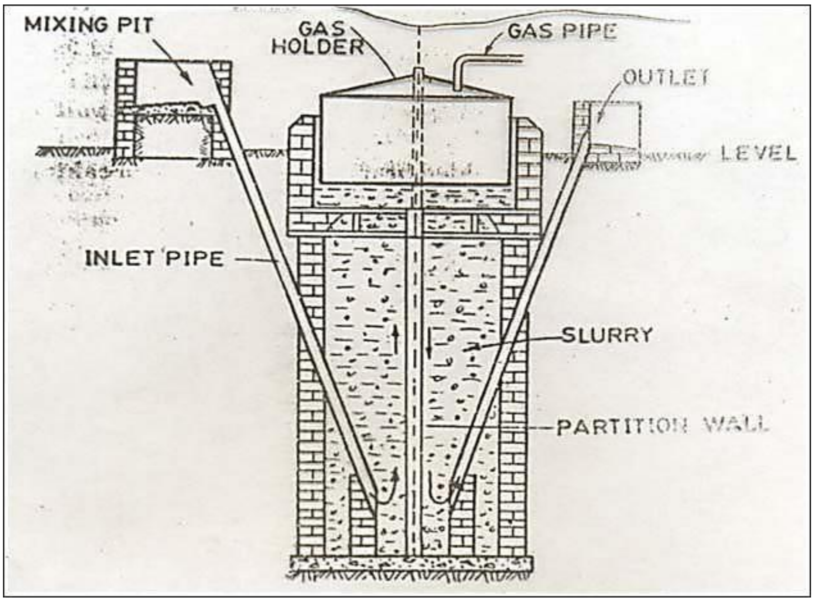
The overall chemical reaction involved in photosynthesis is: 6CO2 + 6H2O (+ light energy) C6H12O6 + 6O2. This is the source of the O2 we breathe, and thus, a significant factor in the concerns about deforestation.

Stages of Photosynthesis:

Photosynthesis is a two stage process. The first process is the Light Dependent Process (Light Reactions), requires the direct energy of light to make energy carrier molecules that are used in the second process. The Light Independent Process (or Dark Reactions) occurs when the products of the Light Reaction are used to form C-C covalent bonds of carbohydrates. The Dark Reactions can usually occur in the dark, if the energy carriers from the light process are present. Recent evidence suggests that a major enzyme of the Dark Reaction is indirectly stimulated by light, thus the term Dark Reaction is somewhat of a misnomer. The Light Reactions occur in the grana and the Dark Reactions take place in the stroma of the chloroplasts.

8. **Explain in detail about KVIC Digester** (Gobar gas generator): (Nov 2012)

Design which is patented by KVIC India under the name "Grah Luxmi" consists of two main parts – (i) Digester or pit, (ii) the gas holder or the gas collectors. It consists of a digester or pit which is for fermentation and a floating drum for the collection of gas. Digester is a well of masonry work, dug and built below the ground level, the depth of the well varies from 3.5 to 6 meters and diameter from 1.2 to 6 meters, depending upon the gas generating capacity and the quantity of raw material fed each day. There is a partition wall in the centre which divides the digested well vertically into two semi cylindrical compartments.



KVIC Type Bio-Gas Plant

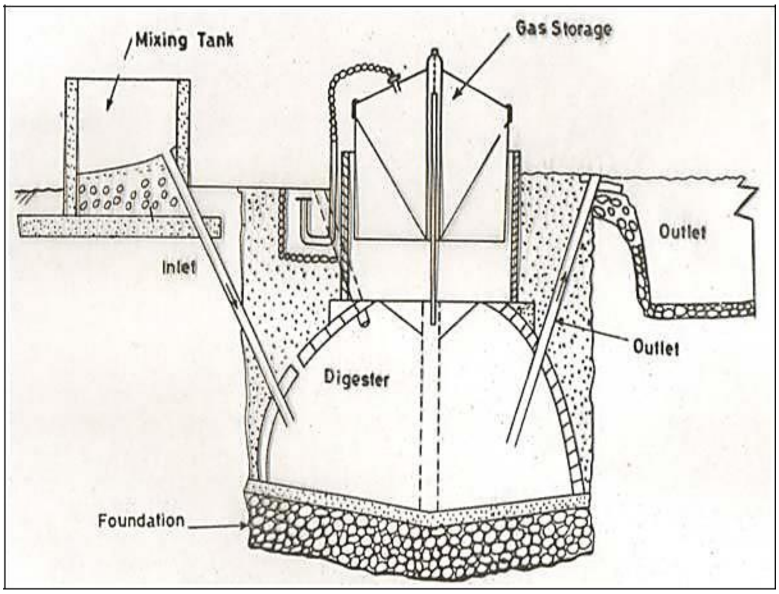
The partition wall is lower than the level of the digester rim and hence it is submerged in slurry when the digester is full. There are two slanting cement pipes which serves the purpose of inlet and outlet. An inlet chamber near the digester at surface level serves for mixing dung and water (slurry) in the ratio of 4:5, flows down the inlet pipe to the bottom of digester. This type of design can hold raw material for 60 days. The outlet chamber which is also at nearly surface level or just a few cm below the level of the inlet chamber. When more slurry is added and both compartments of the digester are full, then equivalent amount of fermented slurry flows out at the outlet and discharges into a composed pit.

Gas holder of the digester is a drum constructed of mild steel sheets, cylindrical in shape with a conical top radial support at the bottom. It fits into the digester like a stopper. It sinks into the slurry due to its own weight and rests upon the ring constituted for this purpose. As the gas is generated the holder rises and floats freely on the surface of the slurry. A pipe is provided at the top of the holder, for flow of gas for usage.

A central guide pipe is provided to prevent the holder from tilting. It is fitted to the frame and is fixed at the bottom in the masonry work. The holder also acts as a seal for the gas. The gas pressure varies between 10-15 cm of water column. The gas before use is passed through a vessel containing soda lime so that it is dried. Generally the pit is deep and narrow, but at places where the water level is low, the design has been modified and the volume has been taken horizontally. The floating drum is metallic and consumes about 40 per cent of the total cost of the plant. Besides, if not properly maintained, the drum corrodes soon and the life of the plant very much gets reduced. Perhaps the cost and the maintenance factors of this type of digesters are prohibitive factors for being not very much liked by users. However, the construction is quite simple and the gas comes out at the constant pressure. Gas is stored in mild steel drum of storage capacity of 30-40% plant size at pressure of about 10 cm water column which is sufficient to carry it upto a length of 20m – 100m depending on size of plant.

9. Explain Pragati Design Biogas Plant

The design has been developed by United Socio-Economic Development and Research Programme (UNDARP) Pune, in order to have a cheaper floating drum biogas plant.



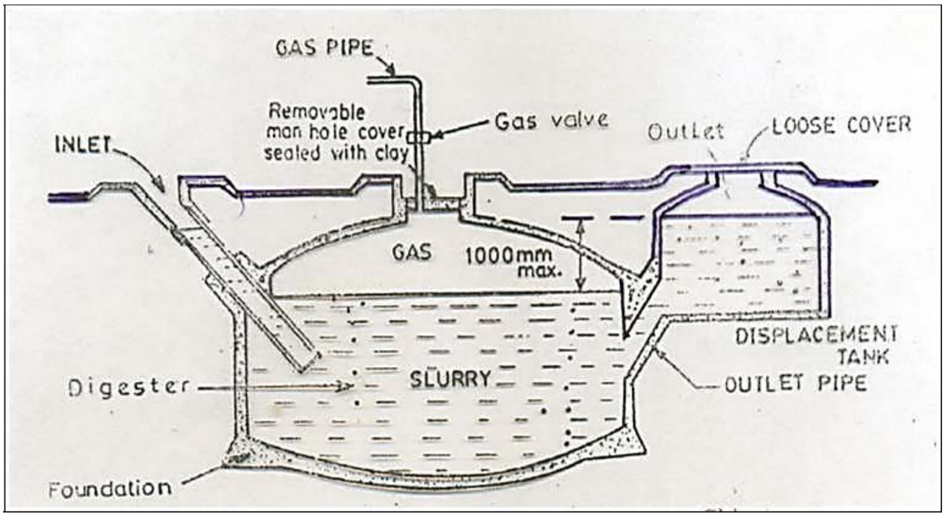
Pragati Type Bio-Gas Plant

In this design the depth of pit is less than KVIC plants so that it can be constructed in hilly and high water table areas. The cost of pragati plant is 20% less than KVIC plant. The foundation of this plant is conical shape, with difference of one feet between outer periphery and its centre so that to reduce the earth digester wall work. It is constructed at the base of the pit with cement, sand and concrete, keeping the site conditions in view so that it can bear the load due to weight of slurry in the digester. The digester of pragati design plant start from the foundation in dome shape there by reducing the constructional area, for same digester volume, thus reducing the cost of the plant.

The wall thickness of digester is kept 75 mm only. Dome shape construction takes place upto a collar base, where a central guide frame is provided. The digester wall above guide- frame is constructed in cylindrical shape. Partition wall is constructed in the digester for $4m^3$ or bigger sizes so as to control the flow of slurry inside the digester. It divides digester into 2 parts separating inlet and outlet. The inlet is through pipe, placed while constructing digester wall. It is used for feeding daily slurry into the digester and is generally of 100 mm dia. The outlet pipe is also 100mm in diameter and fixed while constructing digester wall.The asbestos cement pipe can be used for inlet and outlet. The guide frame is made up angle iron and steel pipe is embedded in the digester wall at top of spherical portion of digester. The central guide pipe holds gas holder which is also made of M.S. sheet and angle iron. It floats up and down along pipe depending on the quantity of gas in the drum.

10. Explain In Detail Janata Type Biogas Plant

This was first developed by the Planning, Research and Action Division, Lucknow in 1978. It is an improved version of the Chinese fixed dome type biogas plant. The foundation of Janata biogas plant is laid at the base of the underground pit on a levelled ground which bears the load of slurry as well as digester wall. Digester is cylindrical in shape, constructed with bricks and cement. It holds the dung slurry in the digester.



Janata Type Bio-Gas Plant

The diameter and height ratio of the digester is kept 1.75:1. The gas is stored in gas portion, which is an integral part of plant between dome and digester where the usable gas is stored. The height of the gas portion is above the inlet and outlet opening of dome, and is equal to maximum volume of the gas to be stored (30 – 40% of plant capacity) and equal to volume of slurry to be displaced at inlet and outlet.

Dome is constructed over the gas portion, with volume of 60% of the plant capacity. It must be constructed very carefully integrating it with digester and gas portion so that no leakage of gas can take place. The gas outlet pipe is fixed at the top of dome for laying the line.

Inlet and outlet portions are constructed for putting the fresh slurry inside the plant and to take the digested slurry out. The discharge of slurry out of the plant is due to pressure of the gas in the plant. Over the inlet portion, an inlet mixing tank is also constructed to mix the dung and water.

Advantages

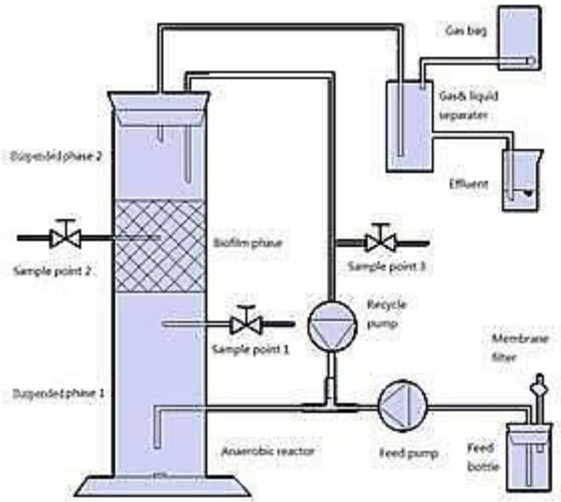
1. Capital investment is low
2. It has no corrosion trouble
3. Heat insulation is better as construction is beneath the ground. Temperature will be constant
4. Cattle and human excreta and by fibrous stalks can be fed
5. No maintenance

Disadvantages

1. No provision for stirring the slurry and hence scum problem is there.
2. Gas production per m^3 of digester volume is less
3. It has variable gas pressure
4. Construction of dome portion is a skilled job and requires thorough training of masons
5. Requires more excavation work
6. Location of defects in the dome and repairing are difficult

11. Explain the Biogas production from Industrial waste.

BIOGAS PRODUCTION FROM INDUSTRIAL WASTE



There are several biogas production technologies being used in agricultural industry and industrial plants that generate various benefits.

At present, systems that are being used include:

1. Up-Flow Anaerobic Sludge Blanket (UASB)

Under this system, waste water will be pumped into the bottom of two-storey tank, comprising sludge bed, consisting 2-5mm granular bacteria, and the sludge blanket. The upper-end of the UASB digester will install Gas Solid Separator to separate gas and prevent bacteria sludge from flowing along with waste water.

2. Anaerobic Fixed Film (AFF) system

This system uses fermentation tank that provides biological firm as an intermediary to fix bacteria on, which could reduce losses of bacteria from water treatment system and make them resilient in case of change in conditions of water waste inflows or excessive organic density.

3. Completely Stirred Tank Reactor (CSTR) system

This technique includes a mixing system, which may stir back biogas generated within the system or use stirring machine to ensure high digestion efficiency and able to cope with high addition of organic substances while reducing time to hold up waste water (HRT) within the digester.

4. Anaerobic Baffle Reactor (ABR) system

This system is a long digester with vertical bars installed to direct flows of water with upflow speed of around 0.2-0.4 meter/hour. This system can be used with waste water that contains high mixture. However, its sizable and requires large space.

5. Modified Covered Lagoon (MCL) system

This anaerobic system is in the rectangular shape, covered by High Density Polyethylene (HDPE) plastic sheet or PVC and use as container for biogas generated. The sheets may cover the whole lagoon or only parts generating methane. The system also increase contact area of bacteria sludge with waste water and develop a system to pull sludge within pipes.

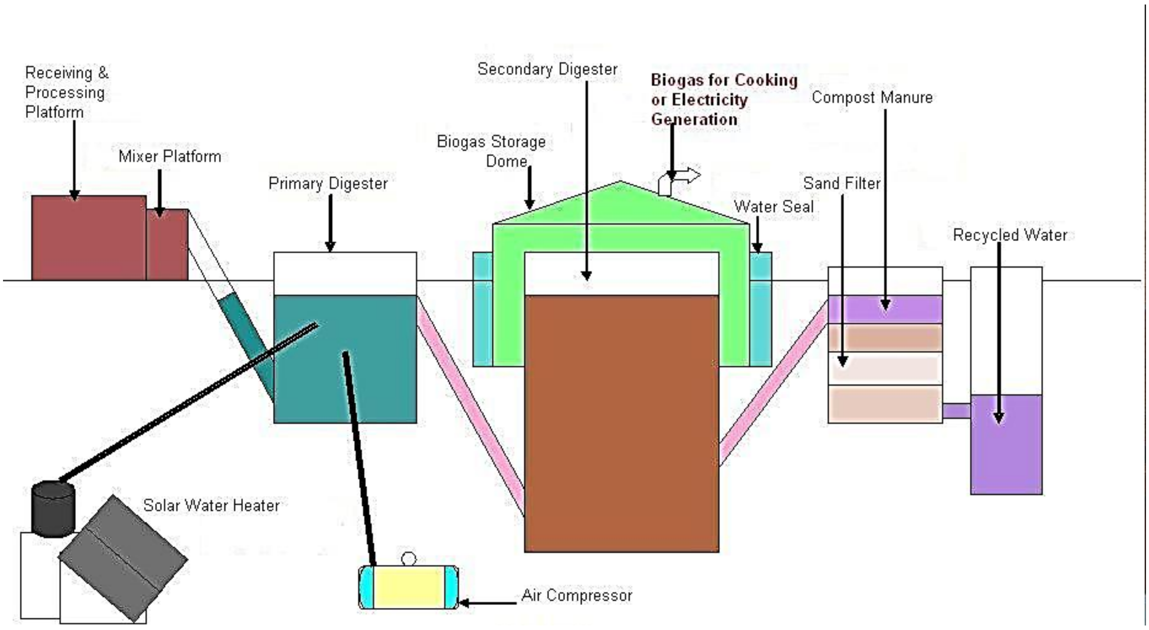
The biogas production technology has been applied in many industries. Frozen food, canned food, fruit juice producers usually use UASB, Covered Lagoon, and anaerobic filter system while cassava flour plants usually use UASB, High Suspension Solids-Up-Flow Anaerobic Sludge Blanket (H-UASB), Anaerobic Baffled Reactor (ABR), Covered Lagoon, Fixed Film, and anaerobic filter. Crude palm oil plant usually use Completely Stirred Tank Reactor (CSTR) or Modified Covered Lagoon (MCL) while slaughter houses usually use plug flow digester, and UASB. Ethanol plants usually use Modified Covered Lagoon (MCL) and UASB.

12. Describe the Municipal waste Biogas plant in detail.

MUNICIPAL WASTE BIOGAS PLANT

The Principle:

Biomass in any form is ideal for the Biomethanation concept, which is the central idea of the Nisargruna Biogas plants. BARC Mumbai based on thermophilic microorganisms and microbial processes develop the design of the biogas plant. The plant is completely gravity based.



Brief process description:

The segregated wet garbage (food waste) is brought to the plant site in bins and containers. It is loaded on a sorting platform and residual plastic, metal; glass and other non-biodegradable items are further segregated. The waste is loaded into a Waste Crusher along with water, which is mounted on the platform. The food waste slurry mixed with hot water is directly charged into the Primary digester.

This digester serves mainly as hydrolysis cum acidification tank for the treatment of suspended solids. For breaking slag compressed air is used for agitation of slurry. Compressed air will also help in increasing aeration since bacteria involved in this tank are aerobic in nature. The tank is designed in such a way that after the system reaches equilibrium in initial 4-5 days, the fresh slurry entering the tank will displace equal amount of digested matter from top into the main digester tank.

Main digester tank serves as a methane fermentation tank and BOD reduction takes place here. The treated overflow from this digester is connected to the manure pits. This manure can be supplied to farmers at the rate of Rs.4-5 per Kg. Alternatively municipal gardens and local gardens can be assured of regular manure from this biogas plant.

The biogas is collected in a dome (Gas holder) is a drum like structure, fabricated either of mild steel sheets or fibreglass reinforced plastic (FRP). It fits like a cap on the mouth of digester where it is submerged in the water and rests in the ledge, constructed inside the digester for this purpose. The drum collects gas, which is produced from the slurry inside the digester as it gets decomposed and rises upward, being lighter than air. Biogas burners will be provided. The biogas can be used for cooking, heating and power generation purpose.

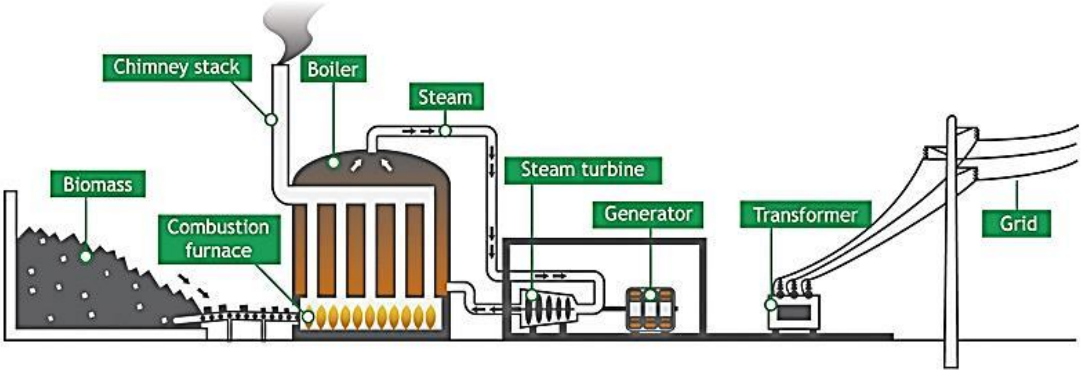
Advantages of Biogas Plant:

- Installation of our biogas plant will enable you to very conveniently treat your entire biodegradable waste and thereby maintain a clean, hygienic, pollution free environment and also avoid all hassles of storage and transportation of waste.
- Hygienic surrounding and airtight top covers for the system, hence no smell and foul odour from this system.
- No flies and mosquitoes problem, birds and stray dogs, cattle menace and also no rats and rodents problem.
- Electricity requirement is very low.
- Water consumption is very low.
- Saving in terms of transport and labour costs for disposal of above waste from source of generation to the disposal site.
- Biogas, a renewable source of non-conventional energy generated, is proportional to the waste loaded per day.
- Maintenance cost is low since the operation of the equipment is periodic. We also undertake annual operation and maintenance contract or only preventive maintenance contract on separate mutually agreed terms and conditions.
- The biogas produced provides smoke free fuel to your kitchen, can be used to fire boilers or for electricity generation.
- The government has allowed 100% depreciation in the year of installation for this non-conventional source of energy and environmentally friendly waste disposal system.
- The high quality manure generated, which would be weed less can be used directly in your garden as it has excellent organically rich fertilizer properties and no foul smell.
- The size of our plant is very compact, can be installed in the area close to the generation of waste.

13. Explain the burning plants and generation of electrical energy from bioenergy.

BURNING PLANTS

Biopower or biomass power, is the use of biomass to generate electricity. There are six major types of biopower systems: direct-fired, cofiring, gasification, anaerobic digestion, pyrolysis, and small, modular.



Most of the biopower plants in the world use direct-fired systems. They burn bioenergy feedstocks directly to produce steam. This steam is usually captured by a turbine, and a generator then converts it into electricity. In some industries, the steam from the power plant is also used for manufacturing processes or to heat buildings. These are known as combined heat and power facilities. For instance, wood waste is often used to produce both electricity and steam at paper mills.

Many coal-fired power plants can use cofiring systems to significantly reduce emissions, especially sulfur dioxide emissions. Cofiring involves using bioenergy feedstocks as a supplementary energy source in high efficiency boilers.

Gasification systems use high temperatures and an oxygen-starved environment to convert biomass into a gas (a mixture of hydrogen, carbon monoxide, and methane). The gas fuels what's called a gas turbine, which is very much like a jet engine, only it turns an electric generator instead of propelling a jet.

The decay of biomass produces a gas - methane - that can be used as an energy source. In landfills, wells can be drilled to release the methane from the decaying organic matter. Then pipes from each well carry the gas to a central point where it is filtered and cleaned before burning. Methane also can be produced from biomass through a process called anaerobic digestion. Anaerobic digestion involves using bacteria to decompose organic matter in the absence of oxygen.

Methane can be used as an energy source in many ways. Most facilities burn it in a boiler to produce steam for electricity generation or for industrial processes. Two new ways include the use of microturbines and fuel cells. Microturbines have outputs of 25 to 500 kilowatts. About the size of a refrigerator, they can be used where there are space limitations for power production. Methane can also be used as the "fuel" in a fuel cell. Fuel cells work much like batteries but never need recharging, producing electricity as long as there's fuel.

In addition to gas, liquid fuels can be produced from biomass through a process called pyrolysis. Pyrolysis occurs when biomass is heated in the absence of oxygen. The biomass then turns into a liquid called pyrolysis oil, which can be burned like petroleum to generate electricity. A biopower system that uses pyrolysis oil is being commercialized.

Several biopower technologies can be used in small, modular systems. A small, modular system generates electricity at a capacity of 5 megawatts or less. This system is designed for use at the small town level or even at the consumer level. For example, some farmers use the waste from their livestock to provide their farms with electricity. Not only do these systems provide renewable energy, they also help farmers and ranchers meet environmental regulations.

Small, modular systems also have potential as distributed energy resources. Distributed energy resources refer to a variety of small, modular power-generating technologies that can be combined to improve the operation of the electricity delivery system.

14. Describe the Biogas from Agricultural waste.

BIOGAS FROM AGRICULTURAL WASTES

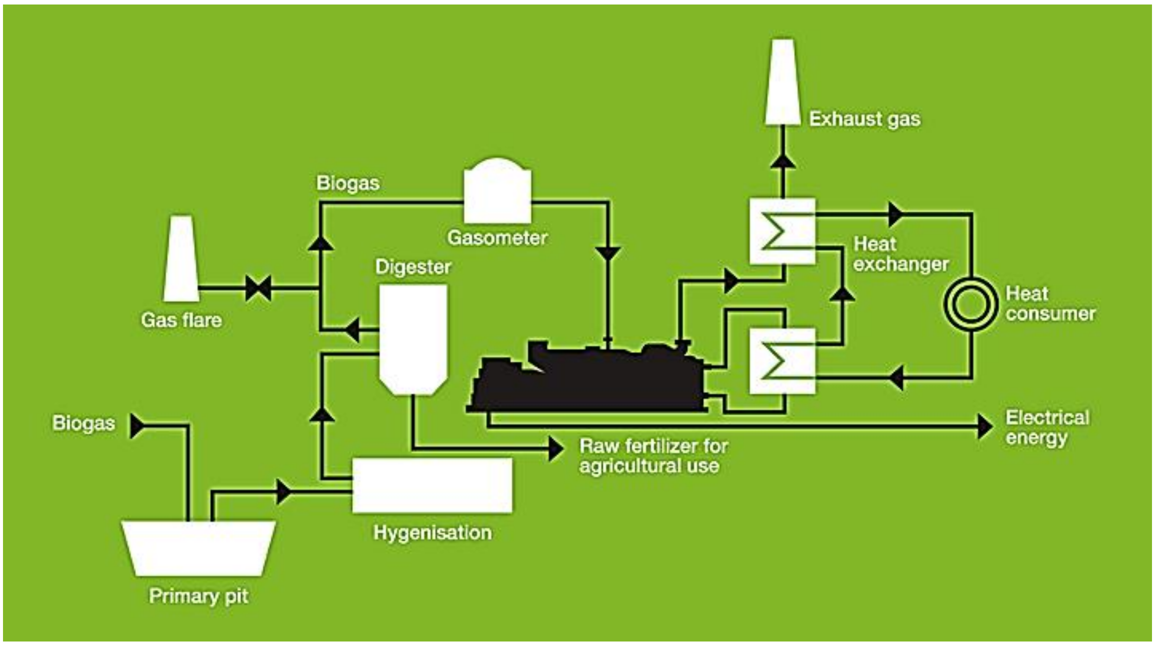
- The main problem with anaerobic digestion of crop residues is that most of the agricultural residues are lignocellulosic with low nitrogen content. To improve the digestibility of crop residues, pre-treatment methods like size reduction, electron irradiation, heat treatment, enzymatic action etc are necessary. For optimizing the C/N ratio of agricultural residues, co-digestion with sewage sludge, animal manure or poultry litter is recommended.
- Several organic wastes from plants and animals have been exploited for biogas production as reported in the literature. Plant materials include agricultural crops such as sugar cane, cassava, corn etc, agricultural residues like rice straw, cassava rhizome, corn cobs etc, wood and wood residues (saw dust, pulp wastes, and paper mill.
- Others include molasses and bagasse from sugar refineries, waste streams such as rice husk from rice mills and residues from palm oil extraction and municipal solid wastes, etc. However, plant materials such as crop residues are more difficult to digest than animal wastes (manures) because of difficulty in achieving hydrolysis of cellulosic and lignocellulosic constituents.
- Crop residues can be digested either alone or in co-digestion with other materials, employing either wet or dry processes. In the agricultural sector one possible solution to processing crop biomass is co-digestion together with animal manures, the largest agricultural waste stream. In addition to the production of renewable energy, controlled anaerobic digestion of animal manures reduces emissions of greenhouse gases, nitrogen and odour from manure management, and intensifies the recycling of nutrients within agriculture.
- In co-digestion of plant material and manures, manures provide buffering capacity and a wide range of nutrients, while the addition of plant material with high carbon content

balances the carbon to nitrogen (C/N) ratio of the feedstock, thereby decreasing the risk of ammonia inhibition.

- The gas production per digester volume can be increased by operating the digesters at a higher solids concentration. Batch high solids reactors, characterized by lower investment costs than those of continuously fed processes, but with comparable operational costs, are currently applied in the agricultural sector to a limited extent.
- Codigestion offers good opportunity to farmers to treat their own waste together with other organic substrates. As a result, farmers can treat their own residues properly and also generate additional revenues by treating and managing organic waste from other sources and by selling and/or using the products viz heat, electrical power and stabilised biofertiliser.

Agricultural Biogas

Agricultural biogas plants utilise organic materials found on farms to generate biogas, a renewable fuel source and in turn renewable power through cogeneration / combined heat & power. The plant may be designed to accept energy crops that have been grown specifically to input into the digestion facility or agricultural wastes. These crops are typically ensilaged and stored in clamps or hoppers and are continuously fed into the digester throughout the year. In India biogas plants may be called gober gas plants.



Energy Crops and Feedstocks for Biogas Production

Typical energy crops for biogas production can include:

- Maize
- Grass
- Wheat
- Rye
- Triticale

Alternatively other organic materials such as waste products may be used including:

- Slurry.
- Manure.
- Vegetable waste.
- Glycerol – from biodiesel manufacture.

Economics of Agricultural Biogas

Agricultural biogas plants typically generate returns via the sale of electricity alone, this means that the gas engine is of particular importance for the success of the plant. Gate fees as a charge for the acceptance of waste materials may be low or none-existent. If the farmer grows energy crops to feed into the plant then there is a cost associated with producing the feedstock. These two factors make it essential for the farmer to have an engine with the maximum levels of availability (running time per year) and the highest levels of electrical efficiency, in order to convert the gas to the maximum level of electrical output.

PONDICHERRY UNIVERSITY QUESTIONS

2 MARKS

1. What is meant by biomass gasification?(Nov 2012)
2. List the factors affecting bio digestion or generation of gas.(Nov 2013)
3. How bio gas is produced (Nov 2013)
4. what are the constituents of bio gas (April/May 2012)
5. Classification of biogas plant (April/May 2012)

11 MARKS

1. Explain in detail about KVIC Digester (Gobar gas generator): (Nov 2012)
2. Write briefly about Photosynthesis:(Nov 2013)
3. Explain in details about various types of Biogas power plant (Nov 2012)(Nov 2013)
4. Principles For Production Of Biogas/ how bio mass conversion takes place (Nov 2012)