NON-CONVENTIONAL ENERGY SOURCE

Electrical Engineering

Semester: 2nd

(This e- content is prepared by taking the reference from the internet, youtube, books etc)

COURSE OUTCOMES

After undergoing the subject, the students will be able to:

CO1: Comprehend various renewable and non-renewable sources of energy

CO2: Gain knowledge about working principle of various solar energy systems

CO3: Acquire the detailed concepts of power generation with the wind energy, ocean energy, hydro, geothermal energy, tidal energy, fuel cell.

CO4: Develop basic design of bio gas plant.

CO5: Gain knowledge of different energy storage devices used in renewable energy resources.

DETAILED CONTENTS

UNIT I

Introduction to Energy and Solar Energy

1.1 Classification of Energy Resources: Conventional Energy Resources, Non-conventional Energy Resources, Roles and responsibility of Ministry of New and Renewable Energy Sources. Needs of renewable energy. Targets and Present Status of Renewable Energy Sources in India.

1.2 Solar Energy: Introduction, potential of solar energy in India, Solar Radiation, Principle of conversion of solar radiation into heat, construction and working principle of photo-voltaic cell. Solar cell materials, Difference between solar cell, panel, array, module,Characteristics, important terms related to solar energy, Efficiency of Solar Cells.Applications of solar energy like solar PV system (standalone and grid connected), solar water heating system, solar furnaces, solar cookers, solar lighting, solar water pumping system, solar still. Government schemes and policies.

Bio-Energy and Hydro Energy

2.1 Bio-Energy: Introduction, Biomass energy, Photosynthesis process, Biomass fuels,

Biomass energy conversion technologies and applications, Biomass Gasification, Types and application of gasifier, Types of biogas plants, Factors affecting biogas generation, Environmental impacts and benefits, Future role of biomass , Biomass potential and programs in India.

2.2 Hydro Energy: Introduction, Capacity and Potential, Hydro Power Plant (mini and micro), Environmental and social impacts.

UNIT III

Wind Energy and Geothermal Energy

3.1 Wind Energy: Introduction, Wind energy conversion system, windmills, types of wind mills, selection of site, electricity generation from wind energy, Wind Energy potential and Scenario in India.

3.2 Geothermal Energy: Introduction , Geothermal Resource Utilization like hydrothermal,Geo-pressured hot dry rock, magma, Geothermal based Electric Power Generation, Associated Problems, environmental Effects, prospects of geothermal energy in India.

UNIT IV

Tidal Energy and Mhd

4.1 Tidal Energy: Introduction, Capacity and Potential, Principle of Tidal Power,Components of Tidal Power Plant, Classification of Tidal Power Plants.

4.2 Ocean Energy: Introduction, Ocean Thermal Energy Conversion (OTEC),Principle of OTEC system, Methods of OTEC power generation, prospects of OTEC in India.

4.3 MHD power generation: Principle of working of Magneto Hydro Dynamic (MHD) Power Generation, materials for MHD generators and future prospects, performance and limitations.

UNIT V

Fuel Cell and Energy Storage Devices

5.1 Fuel Cells: Fuel cell definition, difference between batteries and fuel cells, Principle of working of fuel cells ,types of fuel cell, power generation by fuel cell ,conversion efficiency, applications, advantages and disadvantages of fuel cell .

5.2 Energy Storage: Need of energy storage, Different modes of energy storage, Flywheel storage, Superconducting Magnet Energy Storage (SMES) systems, Capacitor, battery,Super **capacitor. Comparison and application.**

PRACTICAL EXERCISES

1. Visit the website of Ministry of New and Renewable Energy Sources and prepare the Datasheet of Potential, Present and Future Scenario of Renewable energy sources in India.

2. Familiarization with the different components used in solar PV plant (standalone and grid connected system), solar water heating system, solar cooker, solar lighting etc.

3. Calculate power flow of a stand-alone PV system with DC load, AC load and battery.

4. To demonstrate "I-V Characteristics and Efficiency of 1kWp Solar PV System" with varying radiation and temperature level.

5. Assemble the components of solar home lighting system & study the system.

6. Assemble the components of solar water heating system system & study the system.

7. Identify Troubleshoot solar PV panel, inverter and solar smart metering system.

8. Identify the specified components of a 1 KW Small Wind Turbine (SWT) system and study them.

9. Estimation of wind speed using anemometer.

10. Study of charging and discharging behavior of a capacitor.

11. Study of charging characteristics of a Ni-Cd battery using solar photovoltaic panel.

12. Identify the prime mover /turbines used in different renewable energy sources for power generation and study them.

13. Study the Performance of fuel cell.

14. Identify the routine maintenance parts of the micro hydro power plant after watching a video.

> Visit nearby renewable power plant and write specification of each components used in that plant.

RECOMMENDED BOOKS

1. S. P. Sukhatme, “Solar Energy”, Tata McGraw Hill Publishing Company Ltd., New Delhi, 1997.

2. B. H. Khan, “Non-Conventional Energy Resources”, The McGraw Hill.

3. J. W. Twidell & A. Weir, “Renewable Energy Sources”, EFN Spon Ltd., UK, 2006.

4. S. P. Sukhatme and J.K. Nayak, “Solar Energy – Principles of Thermal Collection and Storage”, Tata McGraw-Hill, New Delhi.

5. Garg, Prakash, “Solar Energy, Fundamentals and Applications”, Tata McGraw Hill.

6. G.D. Rai, “Non-Conventional Energy Sources”, Khanna Publications, New Delhi, 2011.

7. Godfrey Boyle, “Renewable Energy, Power for a Sustainable Future”, Oxford University Press, U.K., 1996.

8. K. C. Khandelwal & S. S. Mahdi, “Biogas Technology – A Practical Handbook”, Tata Mc Graw Hill.

CHAPTER-1

BASICS OF ENERGY

1.1 Energy: -

The energy of a body is its capacity to do work. It is measured the totalamount of work that the body can do.

- **Different forms of energy:-**
  - i. Electrical Energy
  - ii. Mechanical Energy (kinetic and potential)
  - iii. Chemical Energy
  - iv. Heat Energy(thermal)
  - v. Nuclear Energy
  - vi. Light(radiant)

The S.I unit of energy is Joule or KJ or Watt.h.

1.2 Classification of Energy:-

1. Primary Energy sources
2. Secondary Energy sources

1. **Primary Energy sources:**

   The Energy of sources which can be used directly as they appear in nature.

   Example: -wood, coal, oil, natural gas etc.

2. **Secondary Energy sources:**

   These sources of energy derive from transformation of primary Energy Sources. **Example:-** petrol, that derives from the treatment of crude oil etc.

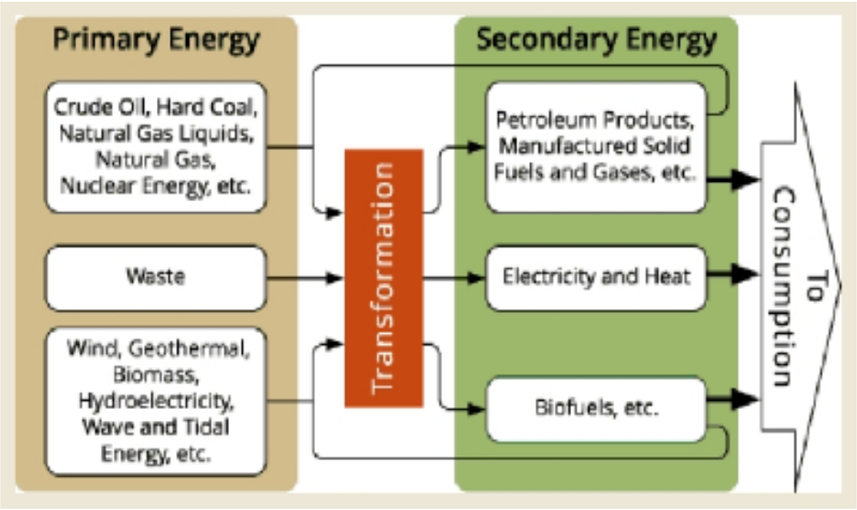


Fig 1.1: Primary and secondary energy sources

1.3 COMMERCIAL AND NON-COMMERCIAL ENERGY:

1. **Commercial Energy: -**The sources of energy are available to user at some cost. These are generally exhaustible.

   Example: -coal, petrol, gas, etc.

2. **Non-Commercial Energy:-**The sources of energy are available to user at free of cost. These are generally renewable.

   Example:-solar energy, firewood.

1.4 Advantages of Electrical Energy over the other forms of Energy:-

Energy in the form of Electrical Energy is most easy to use. The following advantages of Electrical Energy:-

i. It is pollution free and environment friendly.
ii. Electrical energy can be easily converted into other forms of energy.
iii. It can be easily transmitted.
iv. Efficiency of transmission in high.
v. Voltage can be easily stepped up or stepped down as per the requirement.
vi. Control of appliance using Electrical Energy is easy and safe.

1.5 Renewable Energy sources:-

The sources of energy which are being produced continuously in nature and are in exhaustible are called renewable sources of energy (or) non-conventional energy.

1. Solar Energy
2. Wind Energy
3. Tidal Energy
4. Bio-Gas
5. Geo- Thermal Energy
6. Hydro Energy

Fig 1.2: Types of non conventional source of energy

1.6 Importance of Non-conventional source of Energy:

i. The power plants based on renewable do not have any fuel cost and hence negligible running cost.

ii. Renewable energy has low energy density. Thus there is no problem of pollution or ecological balance problem.

1.7 Present Scenario, Future Prospects and Energy Scenario in India:

In 1982 India was created, a separate Department of Non-Conventional Energy Sources (DNES) in the Ministry of Energy to look after all the aspects relating to New and Renewable Energy. The Department was upgraded into a separate Ministry of Non-Conventional Energy Sources (MNES) in 1992 and was rechristened as Ministry of New and Renewable Energy (MNRE), in October 2006.To support the Ministry, there are five institutions consisting of three autonomous bodies i.e National Institute of Solar Energy (NISE), National Institute of Wind Energy (NIWE) and National Institute of Bio Energy (NIBE) and two public sector

undertakings i.e. Indian Renewable Energy Development Agency (IREDA) and Solar Energy Corporation of India (SECI).

In India, use of renewable energy is increasing day by day. Government of India announced in the year 2015, a target for 175 GW cumulative renewable power installed capacity by the year 2022. A capacity of 175GW has been set up by December 2022 constituting more than 26% of the total installed capacity. India has 4th and 4th global positions in the wind and solar power deployment respectively. Since 2013-14 till December 2022, the renewable power deployment has more than doubled. Annually more than 10 millions man-days employment is being created in the sector. Solar power capacity has increased by more than 14 times in the last five years 61.97 GW in December 2022. Solar water heaters and rooftop systems have been promoted in certain government, commercial and residential areas through regulatory intervention such as mandates under building by-laws and its incorporation in the National Building Code. Off-grid and rooftop solar applications have been promoted through the provision of subsidies from the central government.

India has large renewable energy potential from sources such as wind, solar, biomass, small hydro, etc. As per estimates, India has a wind potential of more than 302 GW at a hub height of 100 meter, solar potential of ~750 GW, assuming 3% wasteland is made available, small hydro potential of ~ 20 GW, and bio-energy potential of 25 GW. Further, there exists significant potential from decentralized distributed applications for meeting the hot water requirement for residential, commercial and industrial sector through solar energy and also meeting cooking energy needs in the rural areas through biogas. Renewable energy also has the potential to usher in universal energy access.

Figure 1.3 shows the installed power generation capacity (MW) in India through renewable energy sources upto 31.12.2022.

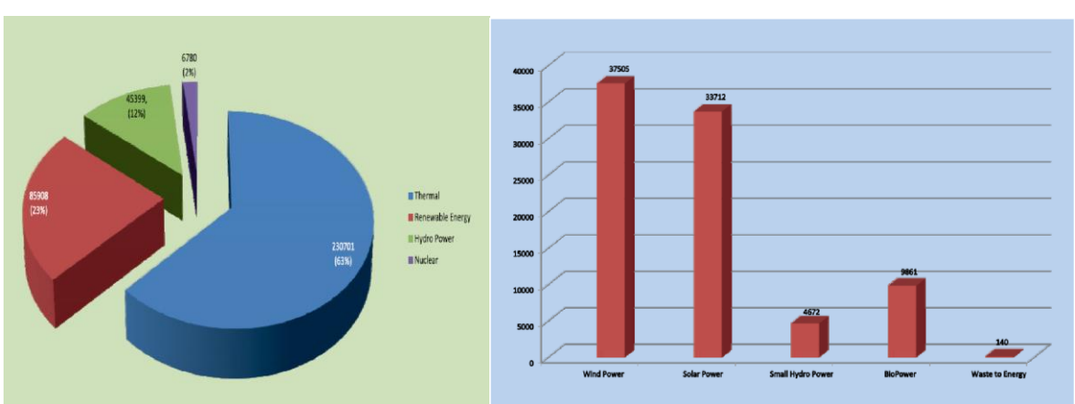
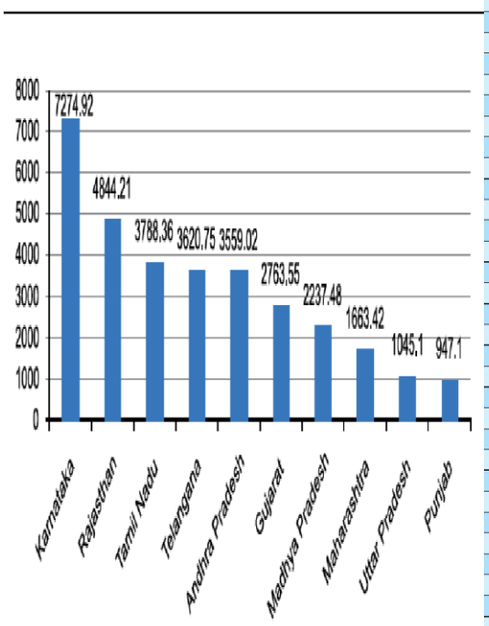


Fig1.3: India-source wise installed power generation capacity (MW) upto 31.12.2022

The installed power capacity in the country is around 408.72 GW as of 30th November 2022. India achieves **166GW of renewable energy capacity till October 2022**.

- **Solar Energy Potential and Achievements:**

As on 31-12-2022, a total solar power capacity installed is 33,7 MW. Fig 1.2 shows the top 10 states in solar Installation as on 31.12.2019 and table 1.3 shows the state wise solar energy potential in the country.



Sr. No.	State/UT	Solar Potential (GWp) #
1	Andhra Pradesh	38.44
2	Arunachal Pradesh	8.65
3	Assam	13.76
4	Bihar	11.20
5	Chhattisgarh	18.27
6	Delhi	2.05
7	Goa	0.88
8	Gujarat	35.77
9	Haryana	4.56
10	Himachal Pradesh	33.84
11	Jammu & Kashmir	111.05
12	Jharkhand	18. 18
13	Karnataka	24.70
14	Kerala	6.11
15	Madhya Pradesh	61.66
16	Maharashtra	64.32
17	Manipur	10.63
18	Meghalaya	5.86
19	Mizoram	9.09
20	Nagaland	7.29
21	Odisha	25.78
22	Punjab	2.81
23	Rajasthan	142.31
24	Sikkim	4.94
25	Tamil Nadu	17.67
26	Telangana	20.41
27	Tripura	2.08
28	Uttar Pradesh	22.83
29	Uttarakhand	16.80
30	West Bengal	6.26
31	UTs	0.79
	TOTAL	748.98

Figure 1.2: Top 10 States in Solar Installation) Table 1.3: State-wise estimated Solar Energy Potential in the Country (capacity in MW as on 31-12-2019

- **Wind Energy Potential and Achievements**

The installed capacity of grid-interactive wind power in the country as on 31.12.2022 is 302 GW and state-wise installed capacity (in MW) as per MNRE is shown in Table

Wind Power Potential in India at 100 meter above ground level

S.No.	State	Wind Potential (MW)
1	Gujarat	84431.33
2	Rajasthan	18770.49
3	Maharashtra	45394.34
4	Tamil Nadu	33799.65
5	Madhya Pradesh	10483.88
6	Karnataka	55857.36
7	Andhra Pradesh	44228.60

S.No.	State	Wind Potential (MW)
8	Kerala	1699.56
9	Telangana	4244.29
10	Odisha	3093.47
11	Chhattisgarh	76.59
12	West Bengal	2.08
13	Puducherry	152.83
14	Lakshadweep	7.67
15	Goa	0.84
16	Andaman & Nicobar	8.43
	Others --	
Total in MW		302251.49
Total in GW		302

Table State wise Wind Power installed

- **BIOMASS POWER / BAGASSE BASED CO-GENERATION (UPTO MARCH 2020) GRID -CONNECTED:**

Ministry has been promoting Biomass Power and Biogases Co-generation Programme with the aim to recover energy from biomass including biogas, agricultural residues such as shells, husks, de-oiled cakes and wood from dedicated energy plantations for power generation. The potential for power generation from agricultural and agro-industrial residues is estimated at about 18,000 MW. Power generation through biogases cogeneration in sugar mills is estimated at around 8,000 MW. Thus the total estimated potential for biomass power is about 26,000 MW. Over 500 biomass power and cogeneration projects with aggregate capacity of 9186.50 MW have been installed in the country up to December 2019.

A cumulative capacity of 9186.50 MW has been commissioned so far mainly in the states of Tamil Nadu, Uttar Pradesh, Karnataka, Andhra Pradesh, Maharashtra, Chhattisgarh, West Bengal and Punjab.

- **SMALL HYDRO POWER:**

Small Hydro Power projects are further categorized into small, mini and micro hydel projects based on their capacity as follows:

Micro hydel ≤ 0.1 MW

Mini hydel > 0.10 MW to ≤ 2.00 MW

Small Hydel > 2.00 MW to ≤ 25.00 MW

The estimated potential of small/mini/micro hydel projects in the country is 21133.65 MW from 7133sites located in different States of India. The national target for SHP is to achieve a cumulative capacity of 5000 MW by 2022, under overall targets of achieving a cumulative grid connected Renewable Energy Power Projects of 175,000 MW. Against this target of achieving an aggregate capacity of 5000 MW by the year 2022, an aggregate capacity of 4671.557 MW been achieved by 31st December 2019 through 1127 small hydropower projects.

1.8 SECTOR-WISE ENERGY CONSUMPTION (Domestic, Industrial, agriculture etc):

Consumption of Coal and Lignite:

- ✓ The estimated total consumption of raw coal by industry has increased from 549.57MT during 2008-09 to 896.34 MT during 2017-18 with a CAGR of 5.01% The annual growth rate from 2016-17 to 2017-18 is 7.06% (Table 1.4).
- ✓ Consumption of Lignite increased from 31.85 MT in 2008-09 to 45.82 MT in 2017-18(Table 1.4).
- ✓ Consumption of Lignite in Electricity Generation sector is the highest, accounting for about 83.7% of the total lignite consumption (Table 1.5).
- ✓ The maximum consumption of raw coal is in Electricity generation, followed by steel industry. Industry-wise estimates of consumption of coal shows that during 2017-18, electricity generating units consumed 576.19 MT of coal, followed by steel & washery industries (58.50 MT), sponge iron industries (8.51 MT) and cement industries (7.70 MT) (Table 1.6)

Table 1.4: Consumption of Energy Sources in India Table 1.5 Industry wise Consumption of Lignite in India

Year	Coal #	Lignite	Crude Oil** MMT	Natural Gas (Billion Cubic Metres)	Electricity (GWh)
	(Million Tonnes)				
1	2	3	4	5	6
2008-09	549.57	31.85	160.77	32.99	5,53,994.71
2009-10	585.30	34.41	186.55	48.34	6,12,644.99
2010-11	589.87	37.69	196.99	52.02	6,94,392.00
2011-12	642.64	41.89	204.12	60.68	7,85,194.00
2012-13	688.75	46.01	219.21	53.91	8,24,300.99
2013-14	724.18	43.90	222.50	48.99	8,74,208.57
2014-15	821.85	46.94	223.24	46.95	9,48,521.82
2015-16	836.73	42.21	232.86	47.85	10,01,190.68
2016-17	837.22	43.16	245.36	50.78	10,61,182.64
2017-18(p)	896.34	45.82	251.93	52.83	11,30,243.84
Growth rate of 2017-18 over 2016-17(%)	7.06	6.17	2.68	4.05	6.51
CAGR 2008-09 to 2017-18(%)	5.01	3.70	4.59	4.82	7.39

(Million tonnes)

Year	Electricity	Steel & Washery	Cement	Paper	Textile	Others *	Total
1	2	3	4	5	6	7	8=2 to 7
2008-09	25.71	-	0.34	0.36	-	6.01	32.42
2009-10	28.14	-	0.38	0.82	-	4.09	33.43
2010-11	29.90	-	0.36	0.84	1.18	6.25	38.53
2011-12	32.06	0.03	1.01	0.63	3.67	4.48	41.88
2012-13	37.20	0.05	1.10	0.69	0.30	3.81	43.15
2013-14	36.34	0.03	1.49	1.29	0.73	4.02	43.90
2014-15	39.47	0.02	1.27	0.65	2.89	2.65	46.95
2015-16	37.56	0.01	0.23	0.43	1.73	2.26	42.21
2016-17	38.82	0.04	0.29	0.53	1.29	2.19	43.16
2017-18(P)	38.34	0.21	1.42	0.83	2.46	2.55	45.82
Distribution (%)	83.68%	0.46%	3.10%	1.81%	5.36%	5.57%	100.00%
Growth rate of 2017-18 over 2016-17(%)	-1.24	508.57	388.32	57.98	90.17	16.78	6.17

Note: (P) -provisional,GWh = Giga Watt hour = 10^6 x Kilo Watt hour , CAGR: compound annual growth rate;Sources:1. Office of Coal Controller, Ministry of Coal 2. Ministry of Petroleum& Natural Gas.3. Central Electricity Authority

Table1.6: Trends in Industry wise Consumption of Raw Coal in India

(Million tonnes)

Year	Electricity	Steel & Washery	Cement	Paper	Textile	Sponge Iron	Fertilizers &chemicals	Brick	Others *	Total
1	2	3	4	5	6	7	8	9	10	11 = 2 to 10
2008-09	377.27	16.58	13.12	2.16	2.53	-	-	-	77.52	489.17
2009-10	390.58	16.45	14.66	2.34	0.27	-	-	-	89.50	513.79
2010-11	395.84	17.26	15.08	2.43	0.28	-	-	-	92.58	523.47
2011-12	437.67	47.86	26.36	2.03	0.26	21.69	2.82	0.13	69.36	608.17
2012-13	485.47	51.70	31.79	2.12	0.30	20.90	2.86	2.01	116.24	713.39
2013-14	493.25	53.05	32.46	1.91	0.36	18.49	2.64	4.01	133.19	739.34
2014-15	497.70	56.24	11.36	1.65	0.42	17.77	2.29	0.09	216.93	804.45
2015-16	517.77	56.83	8.99	1.21	0.27	7.76	2.74	0.07	241.09	836.73
2016-17	535.04	51.98	6.36	1.18	0.24	5.56	2.45	0.10	234.313	837.22
2017-18(P)	576.19	58.50	7.70	1.51	0.24	8.51	2.16	0.11	241.427	896.34
Distribution (%)	64.28%	6.53%	0.86%	0.17%	0.03%	0.95%	0.24%	0.01%	26.93%	100.00%
Growth rate of 2017-18 over 2016-17(%)	7.69	12.54	21.11	27.86	-2.88	53.09	-11.73	15.15	3.04	7.06
CAGR 2008-09 to 2017-18(%)	4.33	13.44	-5.19	-3.51	-21.13				12.03	6.24

Consumption of Crude Oil and Natural Gas:

- ✓ The estimated consumption of crude oil has a steady increased from 160.77 MMT during 2008-09 to 251.93 MMT during 2017-18 with CAGR of 4.59%. It increased from 245.36MMT in 2016-17 to 251.93 MMT in 2017-18 registering a growth of 2.7% (Table 1.4).
- ✓ The maximum use of Natural Gas is in fertilizers industry (27.78%) followed by power generation (22.77%) and 16.25% natural gas was used for domestic fuel for transport sector. (Table 1.7).

Table 1.7 INDUSTRYWISE OFF-TAKE OF NATURAL GAS IN INDIA

(Billion Cubic Metres)

Year	Energy Purpose							
	Power Generation	Industrial Fuel	Tea Plantation	Transport/ Distribution Network	Refinery	Internal consumption	Miscellaneous	Total
1	2	3	4	5	7	8	9	10
2008-09	12.60		0.15	6.01	-		3.42	22.19
2009-10	21.37	-	0.17	2.57	-		7.27	31.37
2010-11	25.79	-	0.19	3.43	-		7.55	36.95
2011-12	22.63	0.28	0.18	5.60	4.26	0.39	9.36	42.42
2012-13	16.08	0.27	0.18	5.78	3.89	0.39	8.25	34.56
2013-14	11.28	0.16	0.20	5.84	3.97	0.37	7.59	29.46
2014-15	10.72	0.39	0.18	5.42	4.58	0.35	6.08	27.72
2015-16	10.89	0.40	0.19	5.46	5.08	0.41	4.25	26.68
2016-17	11.62	0.69	0.18	7.35	5.37	0.47	3.86	29.53
2017-18(P)	12.03	0.87	0.19	8.58	6.53	0.50	3.36	32.06
Distribution (%)	**22.77**	**1.65**	**0.36**	**16.25**	**12.37**	**0.95**	**6.35**	**60.68**
Growth rate of 2017-18 over 2016-17 (%)	**3.55**	**26.86**	**2.85**	**16.80**	**21.56**	**6.38**	**-12.97**	**8.54**

Consumption of Petroleum Products:

- ✓ High speed diesel oil accounted for 39.3% of total consumption (Excluding refinery fuel and loses) of all types of petroleum products in 2017-18. This was followed by Petrol (12.7%), Pet Coke (12.4%) LPG (11.3%), Naphtha (6.1%) .
- ✓ Sector-wise consumption of different petroleum products reveals that Reseller/Retail contributes 54% in the total consumption followed by Domestic sector with contribution 18 %.

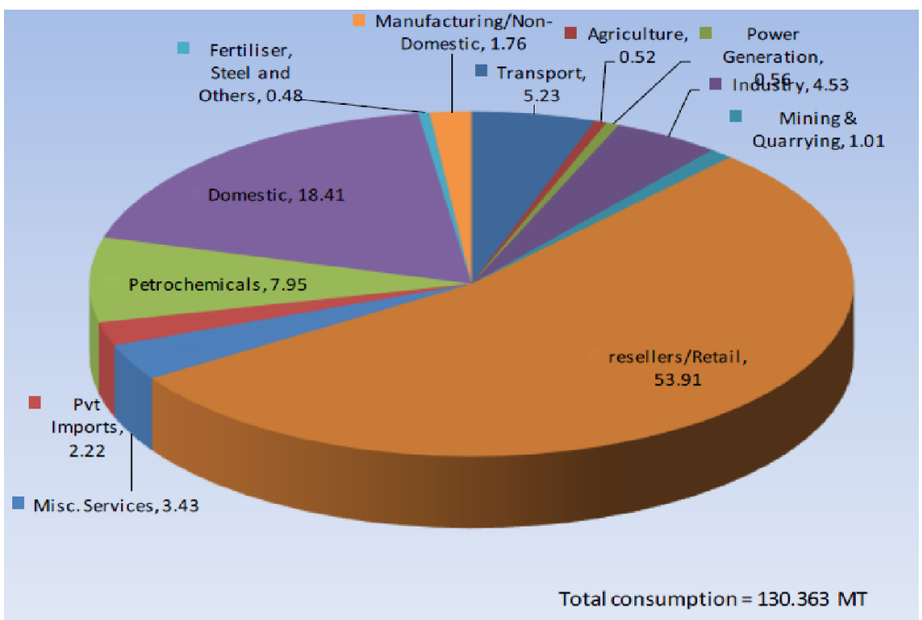


Fig 1.5: Sector-wise Consumption of Petroleum Products during 2017-18

Consumption of Electricity:

- ✓ The estimated electricity consumption increased from 553995 GWh during 2008-09 to 11, 30,244GWh during 2017-18, showing a CAGR of 7.39%. The percentage increase in electricity consumption is 6.51% from 2016-17 (10, 61,183GWh) to 2017-18 (11, 30,244 GWh) (Table 1.7).
- ✓ Of the total consumption of electricity in 2017-18, industry sector accounted for the largest share (41.48%), followed by domestic (24.20%), agriculture (18.08%) and commercial sectors (8.51%).
- ✓ The electricity consumption in industry sector and domestic sector has increased at a much faster pace compared to other sectors during 2008-09 to 2017-18 with CAGRs of 8.39% and 7.58% respectively(Table 1.7)

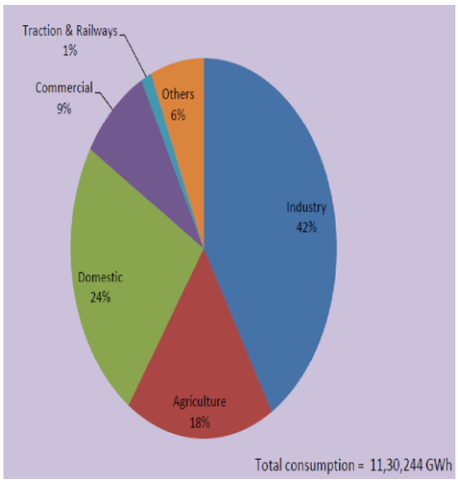


Fig 1.6: consumption of Electricity by sector

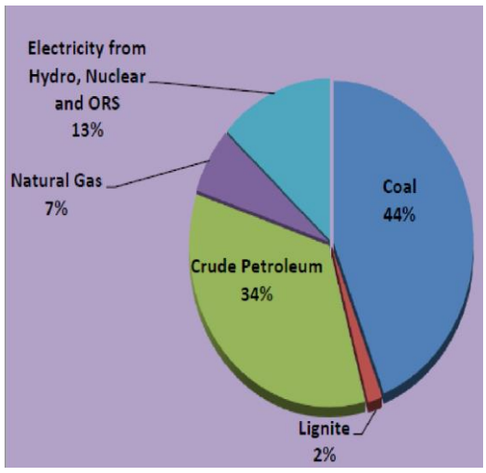


Fig 1.7: source wise consumption of Energy during 2017-18 in India

Q.1 Which is a conventional source of energy?

(a) Solar (b) Radio-active substances

(c) Geo-thermal (d) Wind

Q.2 Which is a non-conventional source of energy?

(a) Fossil fuel (b) Geo-thermal, ocean tides and waves

(c) Radio-active substances (d) Water

Q.3 For satellite the source of energy is

(a) Geothermal (b) wind

(c) Fuel cells (d) seeback effect

Q.4 The disadvantages of renewable source of energy is

(a) low efficiency (b) Cambay

(c) heat (d) Semiconductors

Q.5 What is a conventional source of energy

(a) Solar (b) Radio-active substances

(c) Geothermal (d) Wind

Q.6 Which of the following power plants is the least reliable ?

(a) Wind (b) Tidal

(c) Geothermal (d) Solar

Q.7 Which of the following power plants is most reliable ?

(a) Diesel (b) Hydro-electric

(c) Steam (d) Tidal

Q.8. Hydro-plants are more efficient than thermal plants

(a) Yes (b) No

(c) None of these

Q.9. Geothermal energy is obtained from

(a) Sun (b) oceans

(c) Earth (d) Tides

Q. 10. Total present installed capacity in India is more than

(a) 20,000 MW (b) 40,000 MW

(c) 65,000 MW (d) 1,00,000 MW

1.B 2.B 3.C 4.A 5.A 6.B 7.D 8.A 9.C 10.D

UNIT-1.2

SOLAR ENERGY

2.1 SOLAR ENERGY:

Solar is related with sun. Power or Energy obtained from sun is called solar energy. It is natural source of energy.

- **Types of Rays: -**

Sunlight (rays/radiations) consists of three types of rays:

i. **Ultraviolet Rays:** It has shortest wavelength and is invisible to naked human eye. Most of ultra violet rays emitted by the sun are absorbed by the upper layers of the atmosphere.

ii. **Visible Rays:** It is visible light and consists of seven colors.

iii. **Infrared Rays**: It has shortest wavelength and is invisible to naked human eyes. About 33% of energy received from sun in the form of infra-red rays and produces heat on the earth surface.

2.2 Principle of Conversion of Solar radiation into Heat Energy:-

Solar radiation is converted into heat on the basis of Green House Effect.

Step1: Solar radiation reaches the earth atmosphere some of this is reflected back into space.

Step 2: The reset of sun's energy is absorbed by the land and the oceans, heating the earth.

Step3: Heat (infrared radiation) radiates from Earth towards space.

Step4: Some of this heat is trapped by greenhouse gases in the atmosphere, keeping the Earth warm enough to sustain life.

Step5: Human activities such as burning fossil fuels (coal, oil and natural gas),agriculture and land clearing are increasing the amount of greenhouse gases (carbon dioxide, methane, nitrous oxide, ozone, choloro fluorocarbons etc) released into atmosphere.

Step6: This is trapping extra heat, and causing the Earth's temperature to rise.

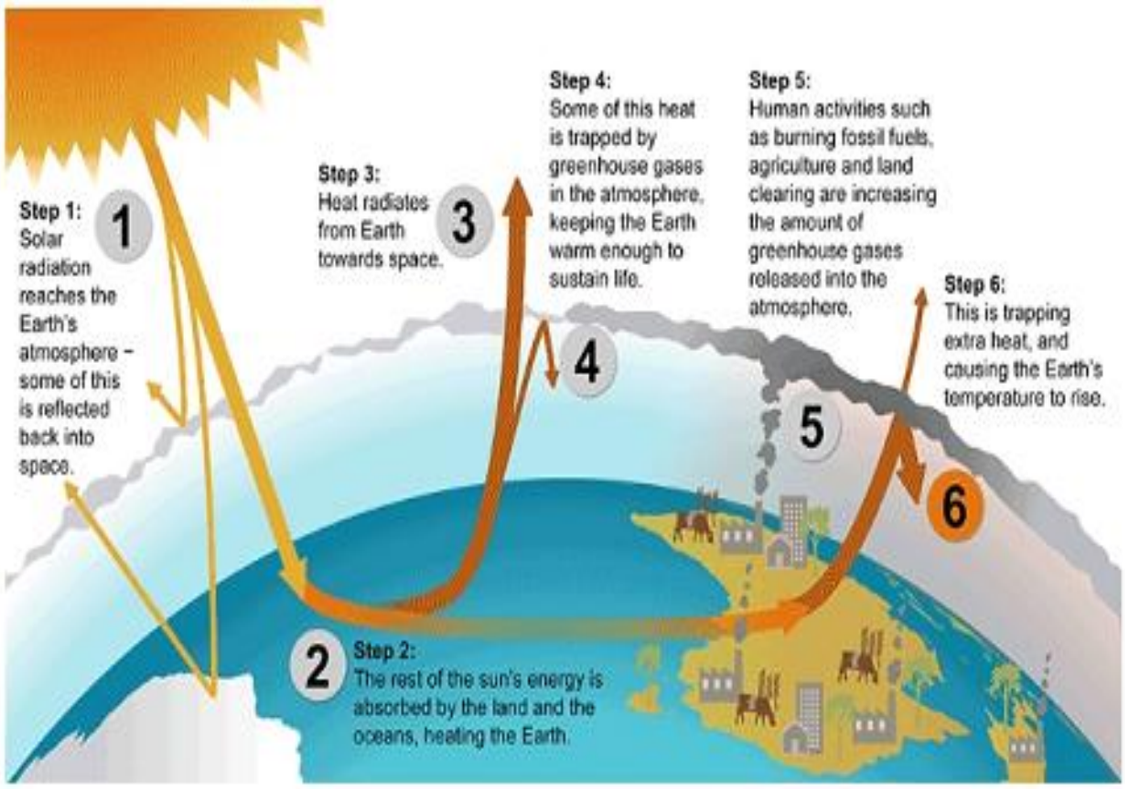


Figure : 2.1 Green house effect

2.3 PHOTO-VOLTAIC CELL:-

It is a semiconductor device which convert energy sunlight directly into Electrical energy is called photo voltaic cell. The voltage induces by the PV cell depends on the intensity of light incident on it. The name photovoltaic is because of their voltage producing capability.

- **CONSTRUCTION:**

The semiconductor materials like arsenide, indium, cadmium, silicon, selenium and gallium reused for making the PV cells. Mostly silicon and selenium are used for making the cell.

As shown in fig below the upper surface of the cell is made of the thin layer of the p-type material so that the light can easily enter into the material. The metal rings are placed around p-type and n-type material which acts as their positive and negative output terminals respectively.

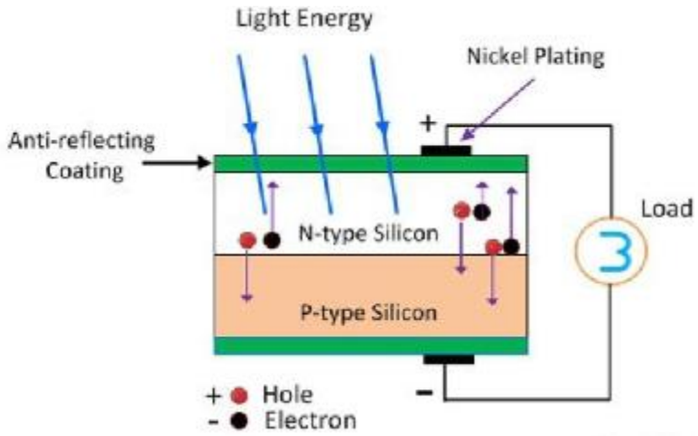


Fig 2.2: P-N junction solar cell

The output voltage and current obtained from the single unit of the cell is very less. The magnitude of the output voltage is 0.6V and that of current is 0.8A.Different combinations of cell (series, parallel and series –parallel combination) are used for increasing the output efficiency.

- **WORKING OF PHOTO- VOLTAIC CELL:-**

When the semiconductor materials absorb lights, the electrons of the materials start emitting energy. This happens because the light consists small energize particles called photons. When the electrons absorb the photons, they become energized and start moving into the material. Because of the effect of an electric field, the particles move only in the one direction and develop current. The semiconductor materials have the metallic electrodes through which the current goes out of it.

As shown in fig 2.2, when light fall on the p-n junction the electrons starts moving from one region to another.

2.4 GENERATION OF ELECTRICITY FROM PHOTO-VOLTAIC CELL

As shown in figure 2.3 below that how the electricity is generated by photo voltaic cell. It consists of:-

i. Solar plate.
ii. Voltage regulator
iii. Inverter
iv. Battery 12v
v. Load

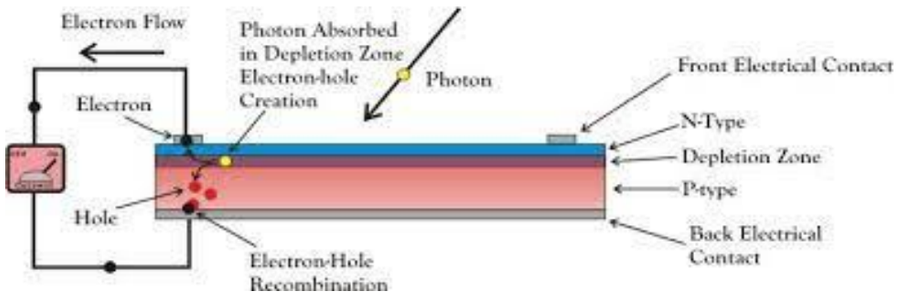


Fig 2.3: Generation of electricity by PV cell

i. Solar plate: it is the combination (series, parallel and series – parallel combination as per requirement) of several PV cell.

ii. Voltage regulator: It maintains the solar voltage.

iii. 12V battery: it is used to store electrical energy obtained from solar cell.

iv. Inverter: It converts DC into AC

2.5 V-I CHARACTERISTICS OF SOLAR CELL

The maximum electrical power one **solar cell** can deliver at its standard test condition. If we draw the **v-i characteristics** of a **solar cell** maximum power will occur at the bend point of the **characteristic** curve.

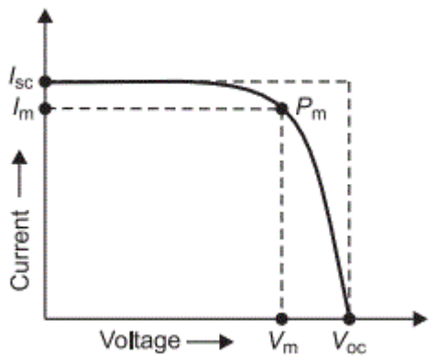


Fig 2.4: V-I Characteristics of solar cell

2.6APPLICATION OF SOLAR ENERGY

1. Solar water heater: -

Solar water heating system (SWHS) is a device which supplies hot water at 60°C to 80°C using only solar thermal energy without any other fuel. It has three main components, namely,

i. Solar Collector(flat plate collector)

ii. Insulated hot water storage tank and

iii. Cold water tank with required insulated hot water pipelines and accessories.

In the case of smaller systems (100 – 2000 litres per day), the hot water reaches the user end, by natural circulation for which the storage tank is located above the collectors. In higher capacity systems, a pump may be used for forced circulation of water.

- **Construction:**

i. ***Flat plate collector:*** The solar radiation is absorbed by Flat Plate Collectors which consist of an insulated outer metallic box covered on the top with glass sheet. Inside there are blackened metallic absorber (selectively coated) sheets with built in channels or riser tubes to carry water. The absorber absorbs the solar radiation and transfers the heat to the flowing water.

ii. ***Hot Water Storage Tank:***The tanks are generally made of stainless steel to avoid corrosion and are insulated to reduce heat losses. They are also fitted with electrical heater as a backup during monsoon days. The tanks may also be made of G.I.

iii. ***Cold Water Tank & Pipelines:***Cold water comes from the over head tank. Hot water from the system is transferred to various utility points through insulated pipelines. A heat exchanger may be provided when the water is hard.

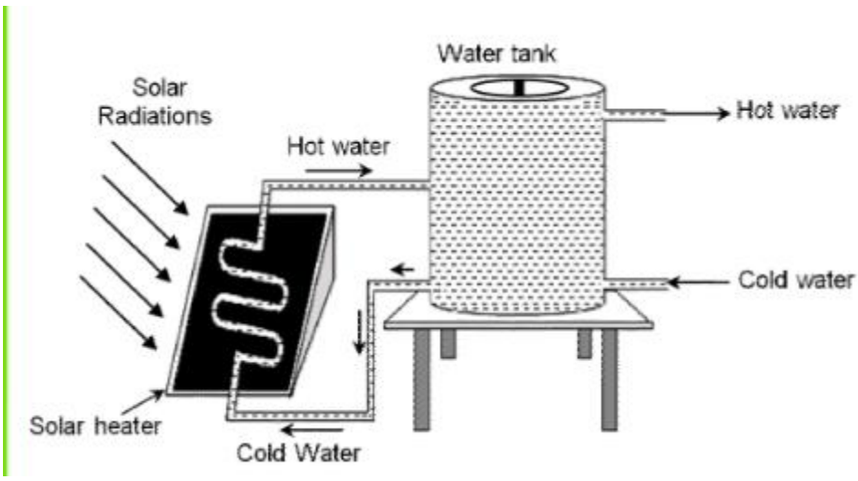


Fig 2.5 Solar water heater system

- **Working:**

The cold water present in the water storage tank enters the copper pipe joined to it at the bottom and pass slowly through the solar collector plate. The sun rays fall on the solar

collector plate, it absorb the solar radiation and transfer the heat energy to the cold water flowing through it. The hot water comes out from the other end of the copper pipe and enters the upper part of the water storage tank as shown in fig 2.5. This hot water is replaced by the cold water present in the tank. In this way, all the water present in the storage tank gradually heated up. In the tank, hot water being lighter remains in the upper part. From the upper part of storage tank, the hot water is supplied to a tap for use.

- **Advantages of solar water heater:-**
  i. Longer life spent 12-15 years.
  ii. Heat the water at 80°C
- **Disadvantages of solar water heater:-**
  i. Initial cost is high.
  ii. Depend on whether condition.
  iii. Occupies large space.

2. Solar furnace:-

A solar furnace is a device that creates heat (high temperature) by concentrating solar radiation through the use of reflectors.

This is achieved by using a curved mirror (or an array of mirrors) acting as a parabolic reflector to concentrate light (insolation) on to a focal point as shown in fig 2.6 below . The temperature at the focal point may reach upto 3,000 degree Celsius, and this heat can be used to generate electricity, melt steel or make hydrogen fuel.

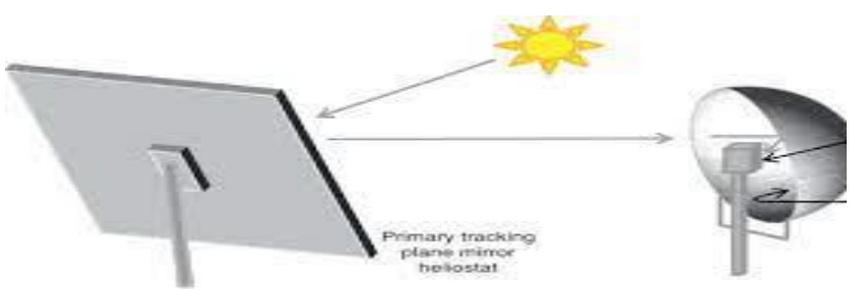


Figure 2.6: solar furnace

- **Advantages:**
  i. Huge heat capabilities
  ii. Lack of required fuel

iii. Easy to use

iv. No running cost

- **Disadvantages:**

i. High initial cost

ii. Unreliable sunshine.

3. Solar cooker:-

The most commonly used form of solar cooker is the box –type solar cooker. A box type solar cooker consists of the following components.

i. **Black Box:** The box is an insulated metal or wooden box which is painted black from the inside to absorb more heat.

ii. **Glass cover:** A cover made two sheets of toughened glass held together in an aluminum frame is used as a cover for box.

iii. **Plane Mirror reflector:** The plane mirror reflector is fixed to the box with the help of hinges. The mirror reflector can be positioned at any desired angle to the box. The mirror is positioned so as to allow the reflected sunlight to fall on the glass cover of the box.

iv. **Cooking containers:** A set of aluminum containers blackened from the outside are kept in Box

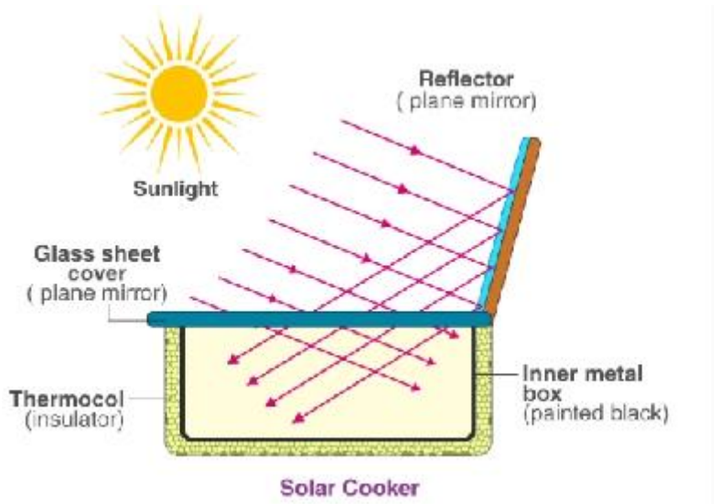


Figure 2.7 solar cooker

- **Working:**

The solar cooker placed in sunlight and a plane mirror reflector is adjusted in such a way, so that the strong beam of sunlight enters the solar box through the

glass sheet. The blackened metal surfaces in the wooden box absorb infra-red radiations from the beam of sunlight and heat produced raises the temperature of a blackened metal surface to about 100 degree Celsius.

The food absorbs heat from the black surface and gets cooked. The thick glass sheet does not allow the heat to escape and thus, helps in raising the temperature in the box to a sufficiently high degree to cook the food.

- **Advantages:**
  i. It has no fuel requirement. This saves cost as well as the environment
  ii. Food vitamins do not get destroyed when heated
  iii. No maintenance cost.
- **Disadvantages:**
  i. It is less useful in cloudy weather.
  ii. It takes longer time to cook food than a conventional stove or oven
  iii. It might get difficult to cook thick foods.

4. Solar lighting:-

Solar lights work with the help of photovoltaic effect. Solar cells are an important part of solar light because, it can only convert sunlight into direct current (DC) and then converting it to usable alternating current (AC) with the help of inverter which is used by most of home appliances.

Generation of electricity from solar cell is already discussed in section 2.4

The solar street lights are widely used in rural areas and where there is problem of electricity. The solar street lights also work on the principle of the photovoltaic cell. These days it is common to see solar street lamps along these ides of roads as shown in fig 2.8. It absorbs the solar energy during daytime and converts into electrical energy, which is stored in the battery. At the nighttime the map starts automatically and it consumed the electricity already stored in the battery. During the day time the battery gets recharged and the process keeps on repeating every day.

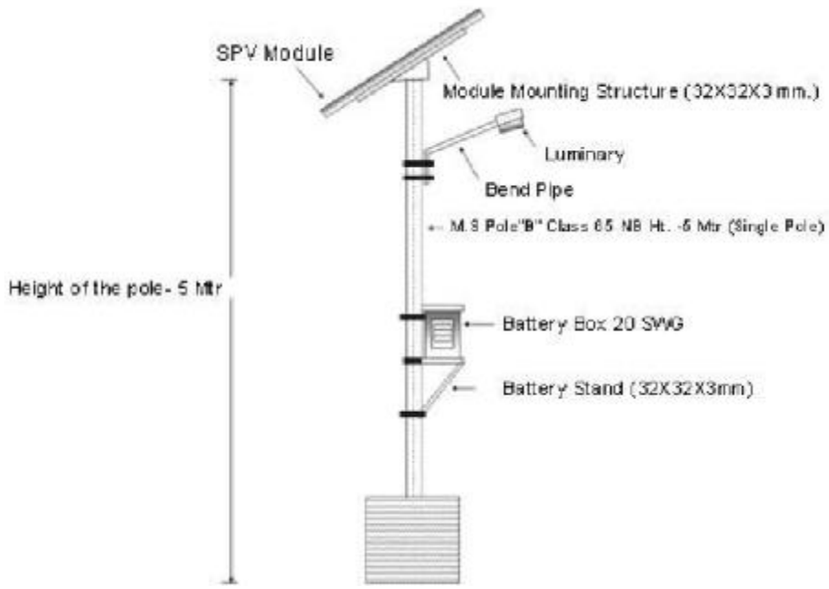


Fig 2.8: solar street lighting system

5. Solar pumping:-

Solar pumping system operates on power generated using solar PV system. The photovoltaic array converts the solar energy into electricity, which is used for running the motor pump set. The pumping system draw water from the open well, bore well, stream, pond, canal etc. The system requires a shadow free area for installation of the solar panel.

- **CONSTRUCTION OF SOLAR PUMPING:-**

It consists of

i. **Solar panel:** It store the energy from solar

ii. **Water pump:** This pump is basically electric pump uses the electricity which is received from the solar panels to work

iii. **Electric motor:** It manage the alternating or direct current

iv. **Controller:** It is used to adjust the output power as well as speed.

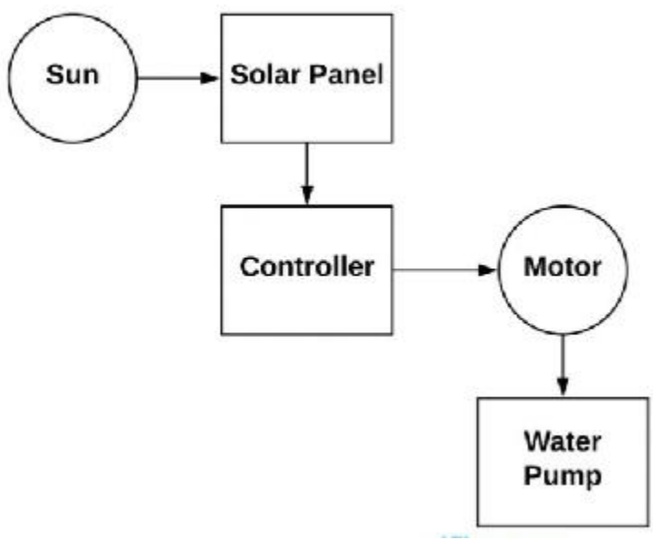


Fig 2.9: Block diagram of solar pumping system

Working:

When the solar energy drops sun rays on the PV panels then the solar panel converts the solar energy into electrical energy. Then electrical energy supplies to the electrical motor to operate the pumping system using cables. By the revolution of the shaft which is fixed to the pump, start to pick up the water from the open well, bore well, stream, pond, canal etc and supplies to the fields.

- **Advantages:**
  i. No fuel cost-a sit uses available free sunlight
  ii. No electricity required
  iii. Longer operating life
  iv. Highly reliable and durable
  v. Easy to operate and maintain
  vi. Eco-friendly
- **Disadvantages:**
  i. It is expensive
  ii. The output of the panel will depend on the weather
  iii. It requires a water storage tank as well as battery
- **Applications:**
  i. Water supply for animals
  ii. Water supply for irrigation, gardens etc
  iii. Water supply for cooking and drinking water supply.

7. **Solar Ponds:-**

A solar pond is a pool of saltwater which collects and stores solar thermal energy. The saltwater naturally forms a vertical salinity gradient also known as a "halocline", in which low-salinity water floats on top of high-salinity water.The layers of salt solutions increase in concentration (and therefore density) with depth. Below a certain depth, the solution has a uniformly high salt concentration.

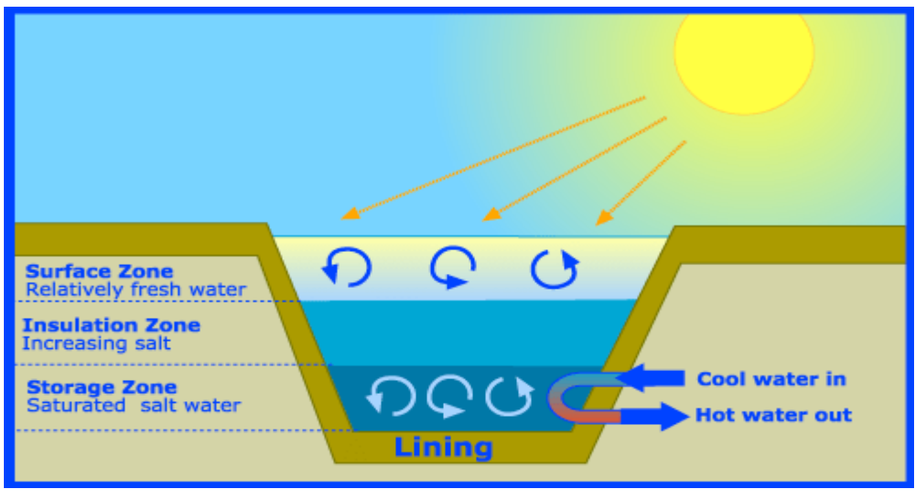


Fig 2.10 Solar Pond

- **Working:**

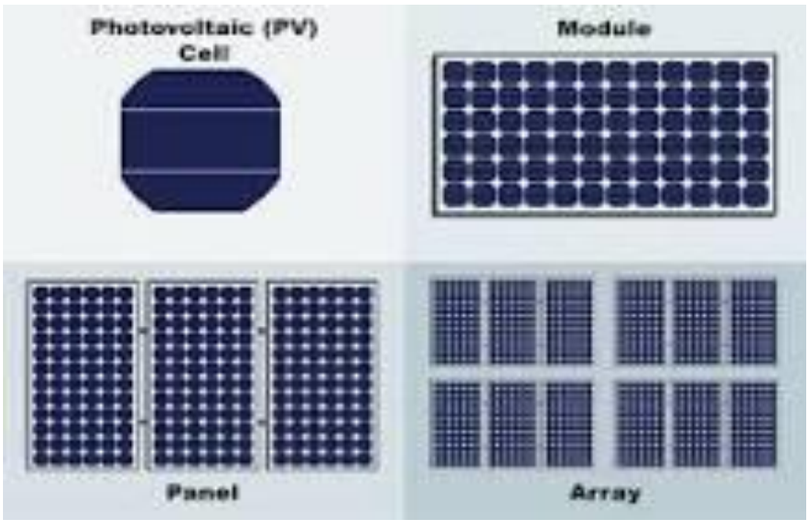
The solar pond works on a very simple principle. It is well-known that water or air is heated they become lighter and rise upward e.g. a hot air balloon. Similarly, in an ordinary pond, the sun's rays heat the water and the heated water from within the pond rises and reaches the top but loses the heat into the atmosphere. The net result is that the pond water remains at the atmospheric temperature. The solar pond restricts this tendency by dissolving salt in the bottom layer of the pond making it too heavy to rise.

A solar pond has three zones. The top zone is the surface zone, or UCZ (Upper Convective Zone), which is at atmospheric temperature and has little salt content. The bottom zone is very hot, 70°– 85° C, and is very salty. It is this zone that collects and stores solar energy in the form of heat, and is, therefore, known as the storage zone or LCZ (Lower Convective Zone). Separating these two zones is the important gradient zone or NCZ (Non-Convective Zone). Here the salt content increases as depth increases, thereby creating a salinity or density gradient. If we consider a particular layer in this zone, water of that layer cannot rise, as the layer of water above has less salt content and is, therefore, lighter. Similarly, the water from this layer cannot fall as the water layer below has a higher salt content and is, therefore, heavier. This gradient zone acts as a transparent insulator permitting sunlight to reach the bottom zone but also entrapping it there. The trapped (solar) energy is then withdrawn from the pond in the form of hot brine from the storage zone.

Difference between Solar cell, Panel, array, module:

An individual photovoltaic device is known as a solar cell. Due to its size, it produces 1 to 2 watts of electricity, but you can easily increase the power output by connecting cells, which makes up a module or panel. And if you have multiple modules or panels connected together, this is called an array.

Photovoltaic cells are connected electrically in series and/or parallel circuits to produce higher voltages, currents and power levels. Photovoltaic modules consist of PV cell circuits sealed in an environmentally protective laminate, and are the fundamental building blocks of PV systems.



Difference between cell, module,panel,array

Q.1 Modern solar cells are made of

(a) Wind (b)Silicon

(c) An oxidant (d) Air electrode

Q.2 The function of ……is to convert the solar energy into thermal energy

(a) Photovoltaic cell (b) Heat.

(c) Pelton (d) Fermentation

3. Name the device which is used to collector solar energy radiation

(a) Solar collector (b)Solar cooker

(c) Solar heater (d) Solar furnace

4. Modern solar cells are made of...

(a) Flat plate (b) pelton

(c) Electrode (d) silicon

5. Main type of solar collector are…… collector.

(a) Flat plate (b) Electrode

(c) Pelton (d) Silicon

6. Flat plate collectors are used for temperature below

(a) 200°C (b) 400°C

(c) 100° (d) 900°

7. Concentrating collectors are used for temperature as high as

(a) 200° (b) 900°C

(c) 1000°C (d) 1100°C

8. The cooking done by the heat energy from the sun is called

(a) solar cooking (b) solar water heater

(c) solar furnaces (d) none of these

Q.9 A solar cell can be made of germanium

a) True b) false

c) both d) none of these

1. b 2.a 3.a 4.d 5.a 6.c7.b 8.a 9.a

UNIT-2

BIO ENERGY AND HYDRO ENERGY

2 .1 BIO-MASS

It is an organic matter which is produce by microrganism, trees and plants both terrestrial (plants grown on land) & aquatic (plant grown in water) residue etc.

The energy obtained from biomass is called **Bio Energy.** It is produced from photo-synthesis as shown in below. In the process of photosynthesis, plants convert radiant energy from the sun into chemical energy in the form of glucose or sugar.

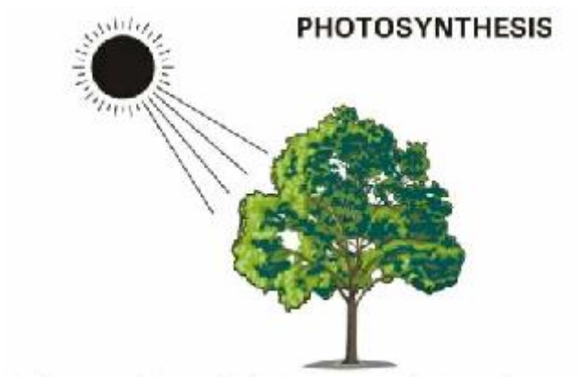


Figure 2.1: photosynthesis

Solar energy+ carbon dioxide +water —>glucose +oxygen

Light + $6CO_2$ + $6H_2O$ —> $C_6H_{12}O_6$ + $6O_2$

We can obtain the Bio energy from biomass in three ways

i. Firstly burn the biomass directly and convert it into heat energy.

ii. Secondly, bio mass is converted into methanol and ethanol used as liquid fuels.

iii. Thirdly biomass is aerobically processed to obtain a gaseous fuel called bio gas.

2.2 Bio-Gas: -

It is the mixture of gases produced by the breakdown of organic matter in the absence of oxygen (aerobically), primarily it consists of methane (CH_4)and carbon dioxide (CO_2).

Biogas can be produced from agriculture waste, manure, municipal waste, plant material, sewage, green waste of food waste. Biogas is a renewable energy source. In India, it is also known as ‘Gobar Gas’.

- **Application of Bio gas**

  i. It is used in house for using food purpose

  ii. Lighting/ Electricity

  iii. Running small engine or transport fuels

2.2METHODS FOR OBTAINING ENERGY FROM BIO-MASS

Bio mass can be used directly as fuel or by converting into liquid or gaseous fuel. According to conversion of biomass, it can be grouped as shown in fig 2.2

1. Thermal conversion method:

   i. Direct Combustion

2. Thermo chemical conversion method:

   i. Pyrolysis

   ii. gasification

3. Biochemical conversion method:

   i. anaerobic digestion

   ii. fermentation

1. Thermal conversation method:

A. **Combustion:**

It is the process of burning of biomass directly to obtain heat. The energy obtained is used for cooking, heating buildings and generating steam.

In biomass power plants biomass is burned in a boiler to produce high pressure steam, which in turn drives a turbine to generate electricity.

Energy efficiency is in such plants could be anywhere between 7 to 27%. However, if biomass is mixed with any fossile fuel, especially coal, efficiency goes up to 30-40%.Burning biomass along with a conventional fossil fuel, especially coal, is called co-firing.

2. **THERMAL CHEMICAL CONVERSION METHOD**:

Thermo-chemical processes do not produce useful energy directly, but under controlled temperature and oxygen conditions. These processes are more convenient and cost effective than the thermal processes. They convert biomass feedstock into energy carriers, such as producer gas, oils or methanol. They are used in internal combustion engines and gas turbines.

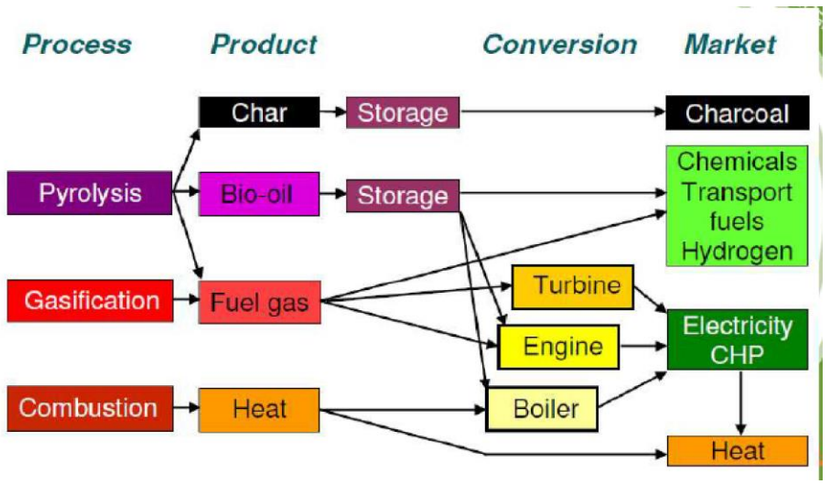


Figure 2.2: Thermo-chemical conversion method

A. Pyrolysis:

Pyrolysis generates biomass energy by heating (not burning) biomass under controlled conditions of high temperature, low or no oxygen, and certain pressure.

End product: The most common end product of pyrolysis is charcoal, which is extensively used in metallurgical processes. Other end products of pyrolysis areliquid or gas. Examples of liquid products are water, tar and oil. Gaseous products include hydrogen, methane and carbon monoxide.

Dry Biomass char + (CO, CO2, H2, H2O (g), CH4) + tars + Ash

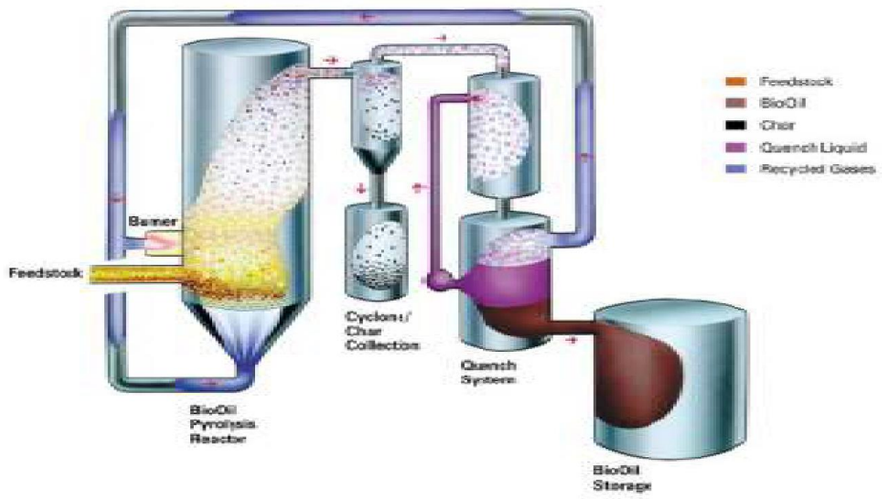


Figure 2.3: Pyrolysis conversion method

B. Gasification:

Gasification is a process that converts the carbonaceous material into CO (Carbon Monoxide), H_2 (Hydrogen) and CO_2 (carbon dioxide).It is obtained at high temperature with a controlled supply of oxygen or steam. This resulting gas mixture is called synthesis gas or producer gas and is a fuel itself. The synthesis gas may be burned directly in gas engines or used to produce methanol and hydrogen.

- **GASIFIER**:

It is an equipment which convert biomass such as wood waste, agriculture waste, human waste, into biogas with high efficiency .This performs the function of gasification process.

- **Steps for gasification**: As shown in fig 2.4

i. DEHYDRATION PROCESS: - Carbonaceous material is derived under 100°C this process is called Dehydration process.

ii. PYROLYSIS:-Carbonaceous material goes for pyrolysis process (at 300°C) char is obtained.

iii. After combustion of char in the presence of oxygen, it forms carbon dioxide (CO_2) gas.

iv. When gasification process of char takes place in the presence of carbon and steam to produce carbon monoxide (CO) and Hydrogen (H2).

v. Thereafter Biomass is obtained .It contains H2, CO,CO2

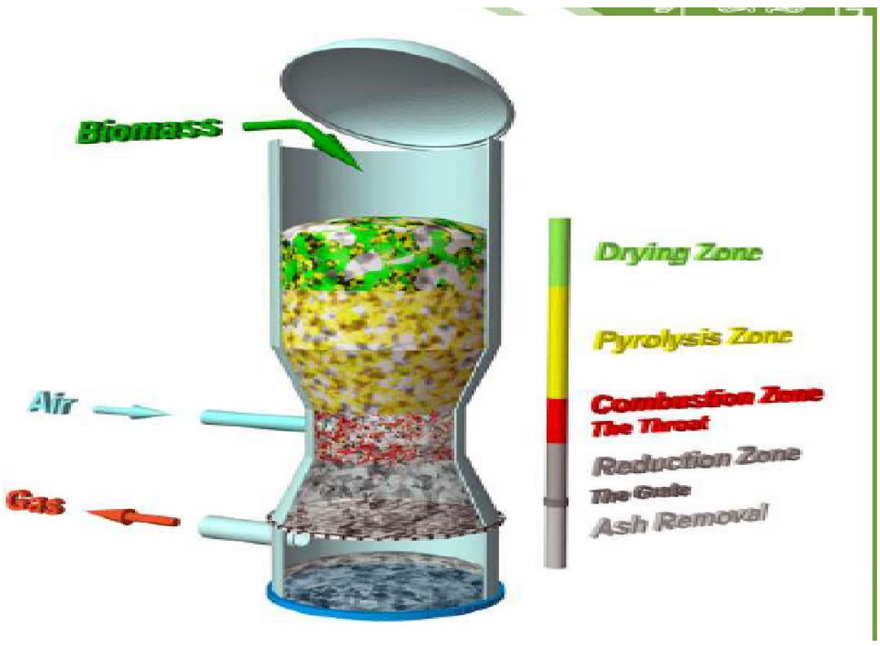


Figure 2.4: Gasification conversion method

- **ADVANTAGES OF GASIFIER:-**

i. Easy maintenance

ii. Easy to obtain

iii. Easy to construction

iv. Better reliable

- **TYPES OF GASIFIER**

i. Up drought gasifier

ii. Down drought gasifier

iii. Fluidised bed gasifier

UP DROUGHT GASIFIER:

In this type of gasifier air enters from below the combustion chamber and synthetic gas leaves from the top of the gasifier as shown in fig below 2.5.In this number of ash content left.

i. **DOWN DROUGHT GASIFIER**:

In this type of gasifier air enter into the combustion chamber from the top and gas leaves at the bottom as shown in figure below 2.5.

ii. **FLUIDISED BED GASIFIER:**

In this type of biomass is fed into a bed of hot inert particles such as sand which kept in fluidized state with air bellowing vertical from bottom as shown in figure below 2.5. Operating temperature is kept the range of 700°C to 1000°C.

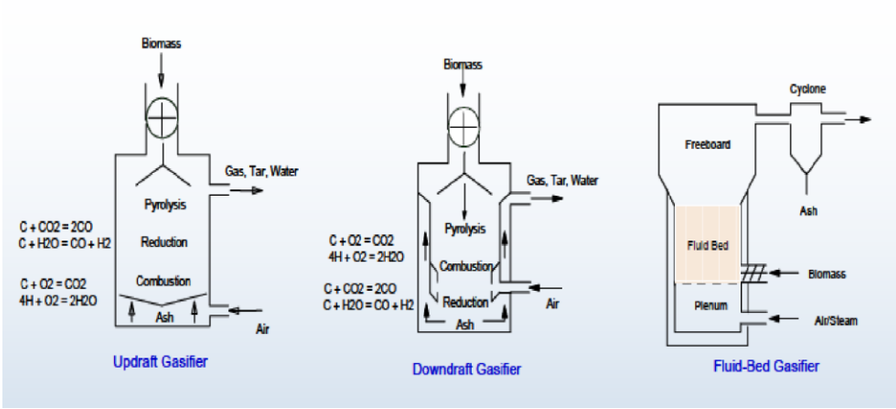


Figure 2.5: updraft, downdraft and fluid bed gasifier

3. **BIO- CHEMICAL CONVERSION METHOD**

Biochemical conversion of biomass involves use of bacteria, microorganisms and enzymes to breakdown biomass into gaseous or liquid fuels, such as biogas or bio ethanol.

The most popular biochemical technologies are

i. Anaerobic digestion

ii. Fermentation

i. Anaerobic Digestion

Anaerobic digestion is the natural biological process which stabilizes organic waste in the absence of air and transforms it into bio fertilizer and biogas. It is are liable technology for the treatment of wet, organic waste.

Organic waste from various sources is biochemically degraded in highly controlled, oxygen-free conditions circumstances resulting in the production of biogas which can be used to produce both electricity and heat.

Anaerobic digestion plants are simple in construction .For producing the biogas; wet sewage sludge, manure (human and animals), animal dung, green plants and crop residues are kept in the hole for about 10 days .It requires at least 80% moisture. After few days biogas is produced due to bacteria decomposition. This biogas contains CO_2, methane and H_2S.This gas can be used directly or by converting it into synthetic natural gas by removing CO_2.

The main drawback of this process is that a large quantity of waste left but now days this waste can be used as animal feeding and bio fertilizer after removing its toxicity.

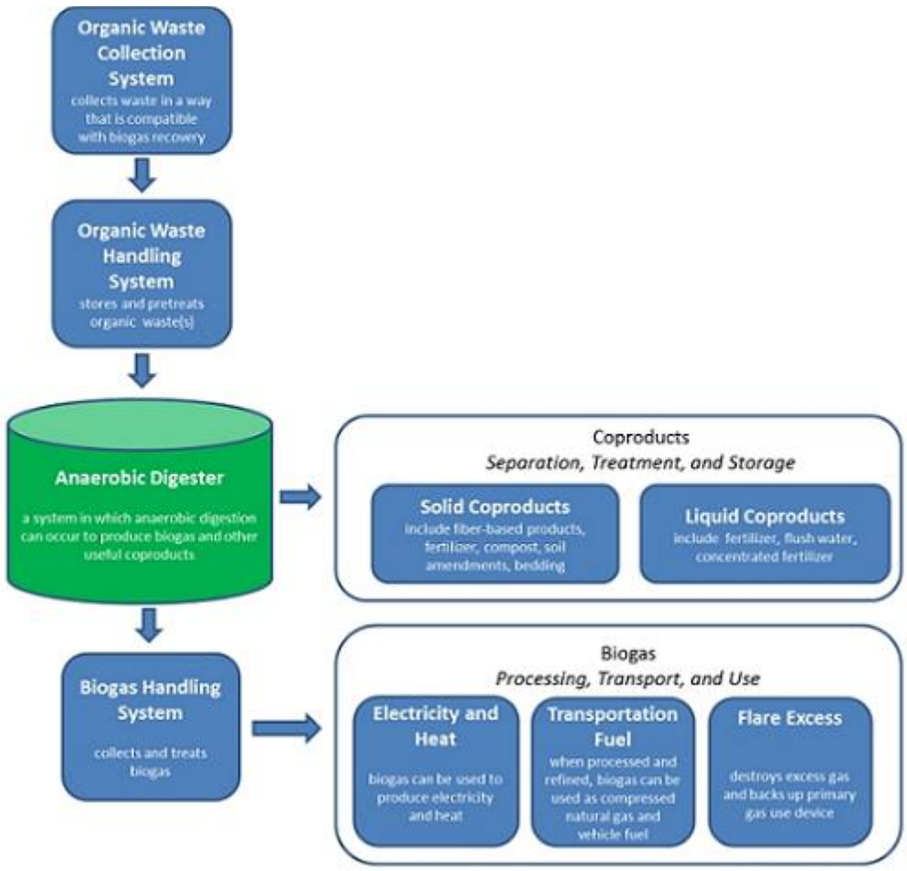


Figure 2.6: Anaerobic Digestion conversion method

ii. Fermentation:

It is a process of decomposition of complex molecules of organic compound under the influence of micro-organism (ferment) such as yeast, bacteria, enzymes etc.

The example of fermentation process is the conversion of grains and sugar crops into ethanol and CO2 in presence of yeast.The ethanol is distilled and dehydrated to obtain a higher concentration of alcohol to achieve the required purity for the use as automotive fuel. The solid residue from the fermentation process can be used as cattle-feed and in the case of sugar cane; the bagasse can be used as a fuel for boilers or for subsequent gasification.

2.3 GENERATION OF POWER BY USING GASIFIER

The block diagram of power generation by using gasifier as shown. In figure below2.7.

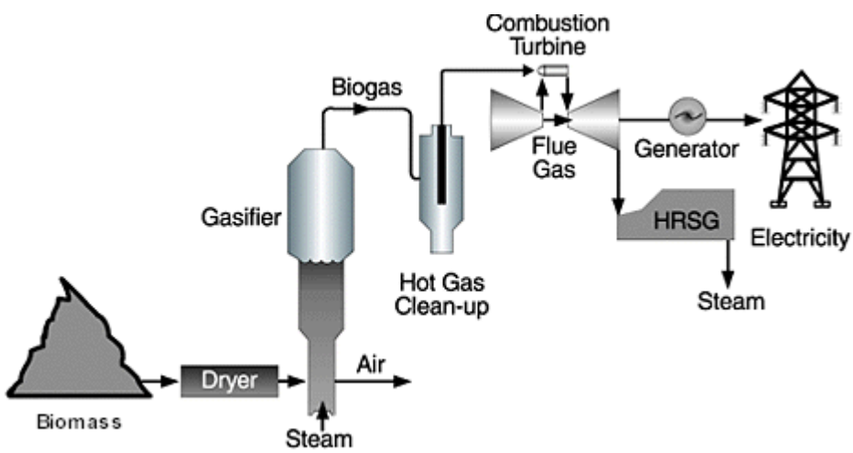


Figure 2.7: generation of power using gasifier

It consists of following:-

1. Gasifier : it is already explained in 2.2

2. **Cylinder:** -synthetic gas is obtained from gasifier and it is cleaning before feeding to cylinder. After feeding the gas in cylinder, it can be use that any place, even in a house for electricity by using mini biogas generators.

3. Biogas Generator: -A generator that operates on bio mass instead liquid fuels is called biogas generator.

2.4 BIOGAS PLANT:

It works on the anaerobic digestion or fermentation process. Biogas is obtained by manure, sewage, municipal waste, plants, and agriculture waste and cow dung.

The fixed dome biogas plant is shown below in fig 2.8.It consist of underground brick masonry compartment (fermentation chamber) with a dome on the top for gas storage. Fermentation chamber and gas holder are combined as one unit.

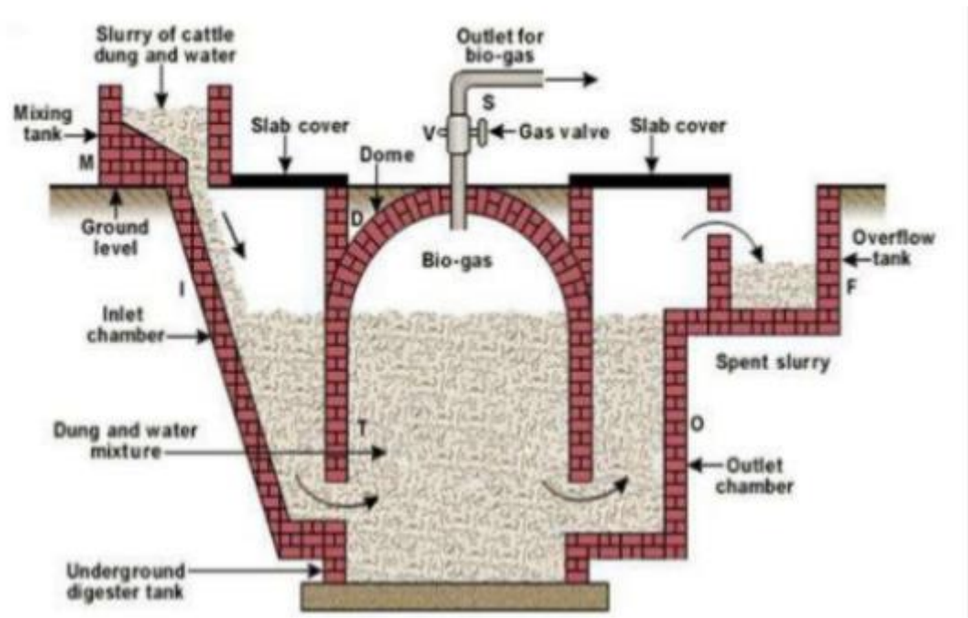


Figure 2.8: fixed dome Biogas plant

In this process biomass mixed with water is filled in the underground digester tank through inlet chamber. In case of overflow, biomass goes into overflow tank through outlet chamber.

After few days due to bacteria reaction on biomass, biogas is produced which is collected from outlet pipe. It can be used directly or can be stored in the tanks.

a) Advantages :

i. Cost of plant is less compare to floating drum type plant

ii. Loss of heat is negligible since these are constructed underground

iii. No corrosion problems as in fixed dome type.

iv. It is maintenance free.

b) Disadvantages:

i. Need skilled labour to operate.

ii. Gas production per m^3 of digester volume is less.

iii. Gas is produced at variable pressure.

HYDRO ENERGY- MINI AND MICRO HYDROPLANTS

2.1 Hydro Power Project Classification

Hydro power projects are generally categorized in two segments i.e. small and large hydro. Ministry of Power, Government of India is responsible for large hydro projects. Responsibility of development of small hydro power (up to 25 MW) is given to Ministry of New and Renewable Energy. Small hydro power projects are further classified as

Size	Unit Size	Installation
Micro	Up to 100 kW	100 kW
Mini	101 to 1000 kW	2MW
Small	1001 to 6000 kW	25 MW

Table 1.1: Hydro Power Project Classification

2.2 Types of Hydro Power Project:

Depending on the capacity, hydro power plants are divided into the following categories:

Category	Capacity
Large Hydro Plant	> 100 MW
Medium Hydro Plant	50 MW to 100 MW
Small Hydro Plant	1 MW to 50 MW
Mini Hydro Plant	100 kW to 1000 kW
Micro Hydro Plant	< 100 kW
Pico Hydro Plant	< 5 kW

Table 1.2: Categories of Hydro Power Project

2.3 Micro hydro power (MHP)

A micro hydro power plant is a type hydro electric power scheme that produces up to 100 KW of electricity from such system is using a flowing steam or water flow.

The electricity from such system is used to power up isolated homes or communication and is sometimes connected to the public grid. Hilly areas with natural water falls on the dam-toe or canal drops are suitable sites for micro-hydropower plants.

Micro- hydropower plants produce nearly constant input power. The only variation result in change of seasons due to the seasonal climate changes and water flow rate. So overall for a certain season, the power is almost constant.

Usually micro hydro installations do not have a dam and reservoir, like large hydroelectric plants has required, only relying on a minimal flow of water is available all the year like natural stream, river or perhaps a waterfall.

Run-of-River micro hydro power system consists of these basis components.

a) Water conveyance- channel, pipeline or pressurized pipeline (penstock) that delivers the water.
b) Turbine, pump or waterwheel- it transforms the energy of flowing water into rotational energy
c) Alternator or generator- it transforms the rotational energy into electricity. The micro-hydropower can be installed with induction generator and synchronous generator. For both on-grid and off –grid modes induction generator gives advantages such as low cost and robust construction. However, synchronous generator is used in off-grid mode.
d) Control Mechanism- to provide static electrical power. It is called governor.
e) Transmission line- to delivers power to its destination

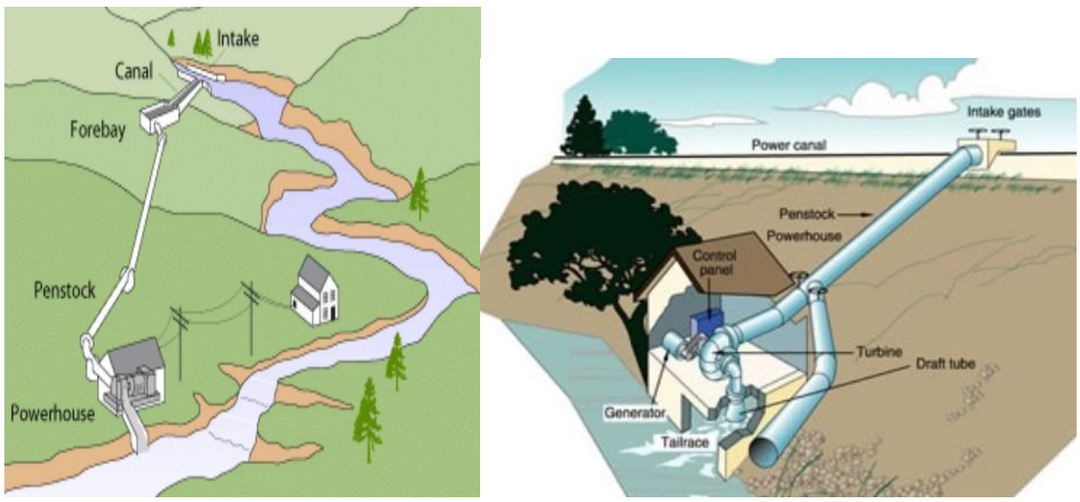


Fig.2.1: Micro and Mini Hydro power plant

Advantages:

a) High efficiency (70-90 %).

b) High capacity factor i.e time generating power throughout the year(typically greater than 50% compared with 10% solar and 30% for Wind)

c) Slow rate of change; the output power varies only gradually from day to day(no from minute to minute)

d) It is a long-lasting and robust technology; systems can readily be engineered to last for 50years or more.

e) Micro hydro most of cases are considered to run –of –river. In other words, any dam or barrage is quite small, usually just a weir, and little or no water is stored. So that low impact on the surrounding ecology.

Disadvantages:

a) Micro hydro systems are limited mainly by characteristics of the site. The most direct limitation comes from small sources with minuscule flow.

b) Likewise, flow can fluctuate seasonally in some areas. Lastly, though perhaps the foremost disadvantage is the distance from the power source to the site in need of energy.

c) The distributional issue as well as the others is key when considering using a micro hydro system.

2.4 Mini Hydro Plants:

A mini Hydro plant is usually able to produce up to 1000kW of electricity per turbine, only using natural flow of water. In small rural community or just for a single remote household, a mini –hydro power plant can be the perfect solution to provide electricity to people. It is mainly seen as a function that next to the river. The water will only pass through via a bypass canal to the turbine, but it will be directed back into the stream.

The most common small hydro projects are of the following types:

a) Run of river
b) Canal falls
c) Dam based outlets and spillways
d) Pumped storage

a) Run of river

In run of river small hydro power schemes, the water is diverted from a river without creating any storage in the river. The output of a run of river plant is subject to the instantaneous flow of the river.

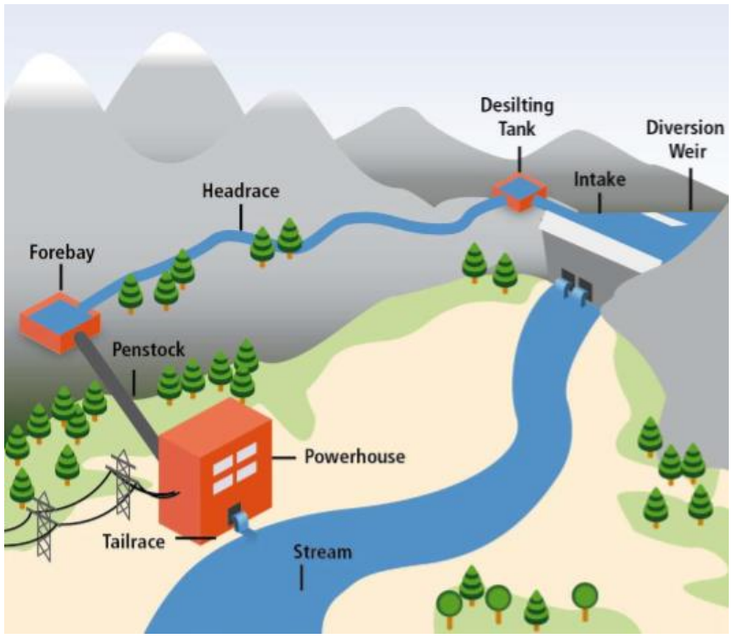


Fig.2.2: Run of river

b) Canal falls

Canal based small hydro power scheme is one which is planned to generate power by utilizing the fall and discharge available in the canal. Falls in the canals are available due to difference in canal slope and topographical slope. These schemes may be planned in the canal itself or in the bye-pass channel.

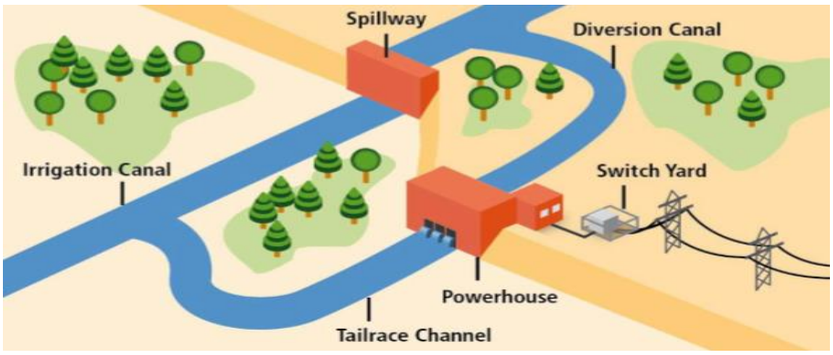


Fig.2.3: Canal Falls

c) Reservoir based schemes- Dam Based Outlets

Reservoir based schemes are those in which water is stored in the river by constructing a dam across the river for the desired use like irrigation, drinking, flood control. Power is generated at the time of release of water from the dam for the derived use of water.

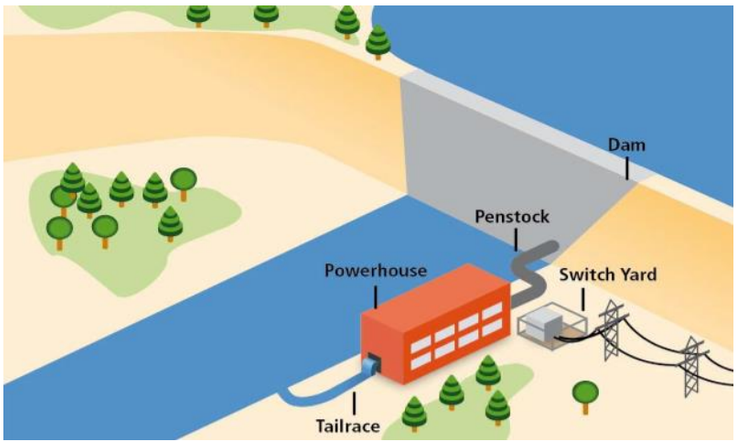


Fig21.4: Reservoir based schemes- Dam Based Outlets

d) Pumped Storage Scheme

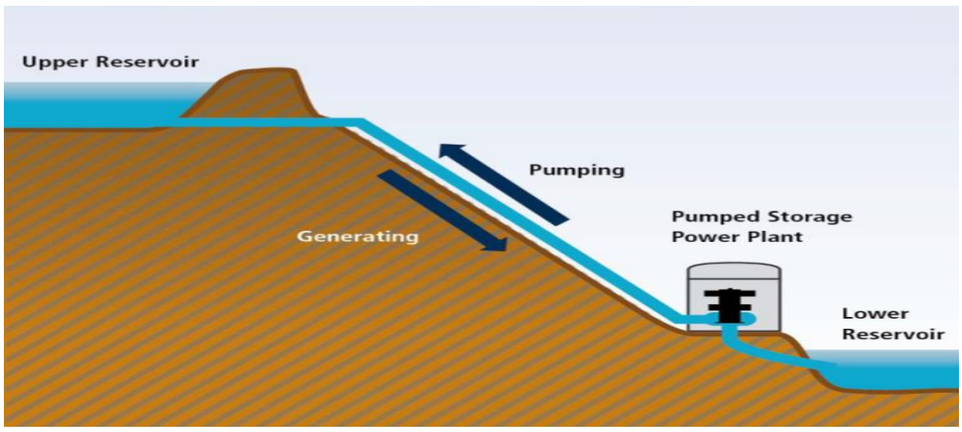


Fig21.5: Pumped Storage Scheme

Pumped storage hydro electricity is a type of hydro electric energy storage used for electrical power system for load balancing. The method stores energy in the form of gravitational potential energy of water, pumped from a lower elevation reservoir to a higher elevation.

Multiple choice Questions

Q.1 Hydroelectric power plant is _____

a) Non-renewable source of energy

b) Conventional source of energy

c) Non-conventional source of energy

d) Continuous source of energy

B

Q.2 Which of the following categories does tidal power fall into?

a) Hydrothermal

b) Hydropower

c) Solar

d) Wind

B

Q.3 Which of the following best describes the working of a tidal barrage for an incoming tide?

a) Incoming tides → generator → barrage → basin

b) Incoming tides → basin → generator → barrage

c) Incoming tides → barrage → basin → generator

d) Generator → barrage → basin → incoming tides

C

Q.4 MHD works on principle of

a) Faradays law b) Magnetic induction law

c) chemical operation d) none

a

Q.5 The…….. power plants do not require any fuel

a) Hydro electric b) hydro power

c) MHD generation d) Hydrograph

Q.6 Small hydro power plans have a capacity in range of

a) 2 MW to 15MW b) 6MW to 13MW

c) 8MW to 16MW d) 9MW to 15MW

c

Q.7 The capacity of mini hydro power generation ranges from

a) 100 kW to 2000 kW b) 100 kW to 1000 kW

c) 200 kW to 5000kW d) 600 kW to 700kW

b

Q.8 Bio gas is a…….. gas.

a) hygienic b) inflammable

c) Flammable d) Anaerobic

c

Q.9 Bio energy is the energy obtained from

a) Bio gas b) fuel

c) Bio mass d) coal

c

Q.10 Gasification has …..conversion efficiency

A) lower b) higher

c) both d) none

c

iv.

UNIT-3

WIND ENERGY AND GEOTHERMAL ENERGY

3.1 Wind:-

Air in motion is called wind and energy obtained from wind is called wind energy.

3.2 wind energy conversion

Wind energy can be converted into electrical energy in wind plants. It generally referred as **WECS** stands for **wind energy conversion system.**

The main components of a wind power plant:

i. Wind turbine

ii. Yaw

iii. Coupler

iv. Hydraulic transmission

v. Electrical generator

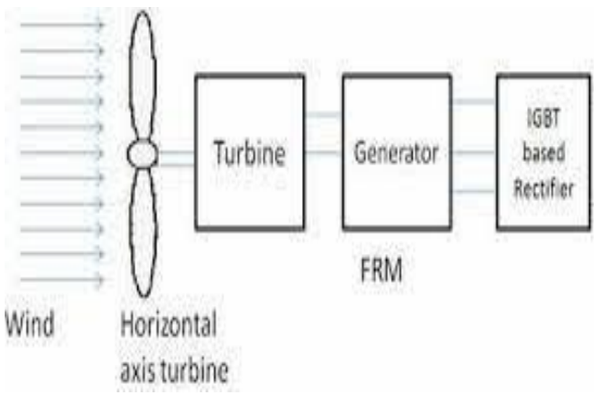


Fig 3.1 Wind Energy Conversion system

i. **Wind Turbine:** This component convert wind kinetic energy into mechanical energy. Blades of the turbine are mounted on the shaft.

ii. **Yaw:** This component is used to change the direction of rotation using gears.

iii. **Coupler:** This component is used to couple turbine with generator.

iv. **Hydraulic Transmission:** This component is used to transfer mechanical energy from top to bottom components.

v. **Electric Generator:** This component converts mechanical Energy into Electrical Energy.

3.3 Wind Mills

It is a wind turbine (Blades) which convert kinetic energy of the wind into rotary mechanical energy.

It works on the principle of momentum.

Momentum= mass * velocity

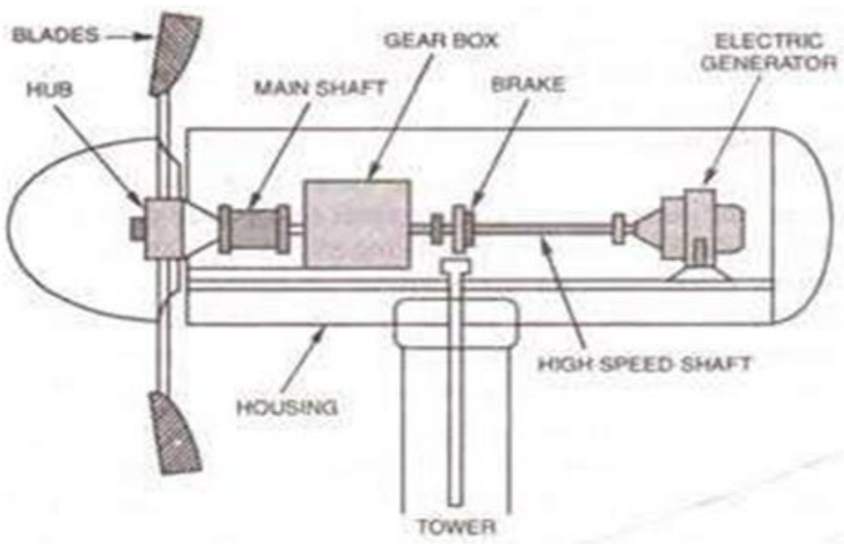


Figure 3.2 wind turbine

a) Lift Force:

When flowing air with momentum strike the downward side of the blade with low pressure it exert the force on the blade of rotor and turn the rotor. This exerted force is called as Lift Force.

Lift force always act perpendicular to the direction of air flow as shown in fig 4.3.

b) Drag Force:

An axial force act in the direction of wind flow is known as Drag force. For efficient operation lift force should be more than drag force.

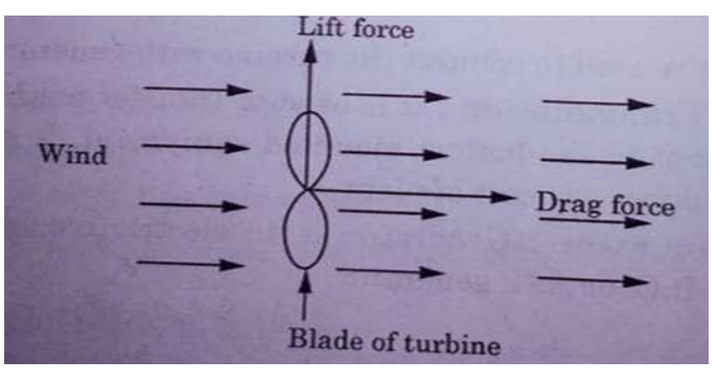


Figure 3.3: Lift and Drag Force

3.4 Types of Wind Mills:

Wind mill or Wind turbine can be classified according to the axis of rotation of turbine.

i. **Horizontal Axis Wind Turbine**

ii. **Vertical Axis Wind Turbine**

i. **Horizontal axis wind turbine**:

A turbine that rotates parallel to the direction of wind is calledHorizontal axis wind turbine.

c) Types of Horizontal Axis Wind Turbine (HAWT):

a) Single Blade Horizontal Axis Wind Turbine

b) Double Horizontal Axis Wind Turbine

c) Multiple Horizontal Axis Wind Turbine

a) Single Blade Horizontal Axis Wind Turbine:

It is also known as Mono Blade Horizontal Axis Wind Turbine. It consists of a long blade of around 10 m mounted on the hub. Single Blade is balanced by using weigh arm as shown in diagram 3.4 (a).

b) Double Horizontal Axis Wind Turbine:

This type of turbine has two blades mounted on the hum as shown in fig 3.4 (b).

c) Multiple Horizontal Axis Wind Turbine:

In this type of turbine many blades are mounted on the hub as shown in fig 3.4 (c).

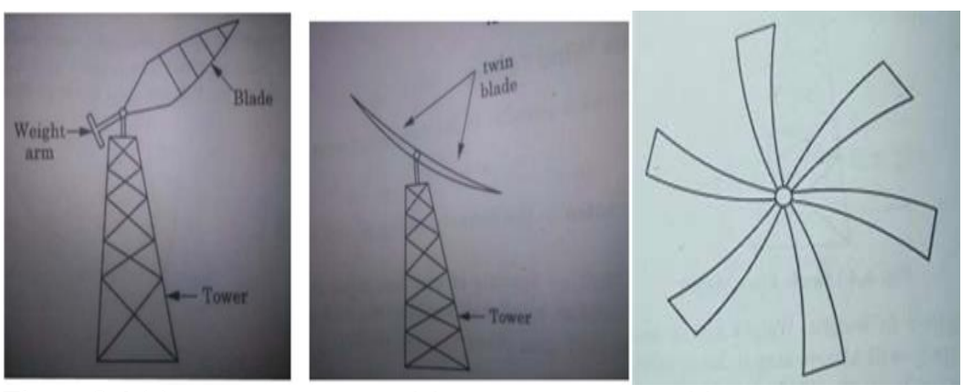


Figure 3.4 (a) Single blade HAWT ; (b) Double blade HAWT; (c) Multiple blade HAWT

d) Advantages of HAWT:

i. It has high efficiency.

ii. It faces the maximum wind so that turbine collects maximum amount wind energy.

iii. In HAWT less vibration occurs.

ii. Vertical Axis Wind Turbine (VAWT):

A turbine whose axis of rotation of blade is perpendicular to the direction of wind is called vertical axis wind turbine.

e) Types of Vertical Axis Wind Turbine (VAWT):

It consist of two types

a) Savonius turbine

b) Darrieus type turbine

a) Savonius type VAWT:

The Savonius turbine is S-shaped if viewed from above. It consists of two half cylinder facing in opposite directions as shown in fig 3.5.

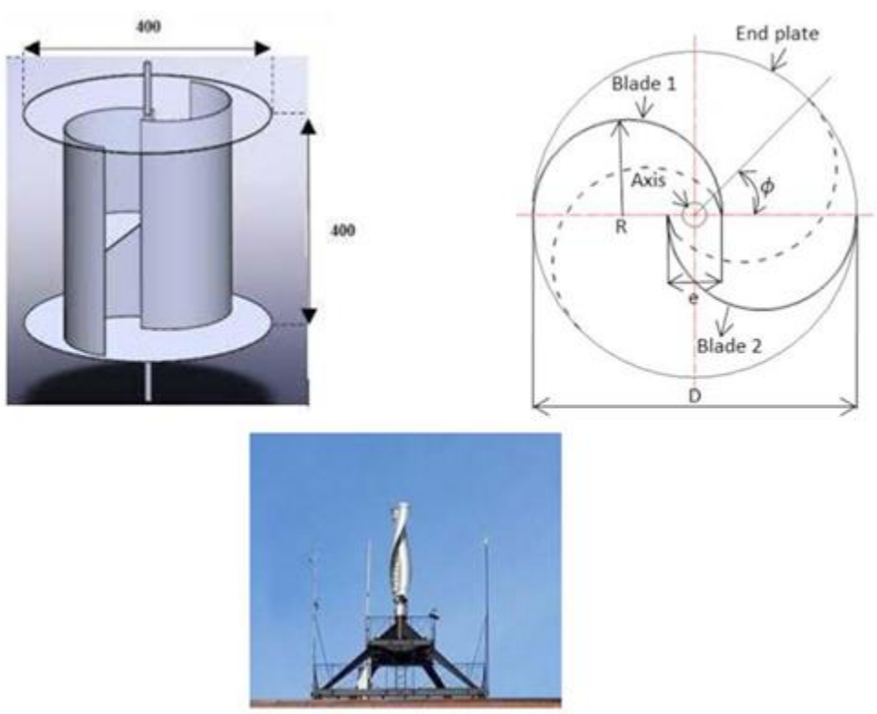


Fig 3.5 Savonius Type VAWT

b) Darrieus Wind Turbine:

The Darrieus turbine is the most famous vertical axis wind turbine. It is characterized by its C- shaped rotor blades which give it its eggbeater appearance. It is normally built with two or three blades.

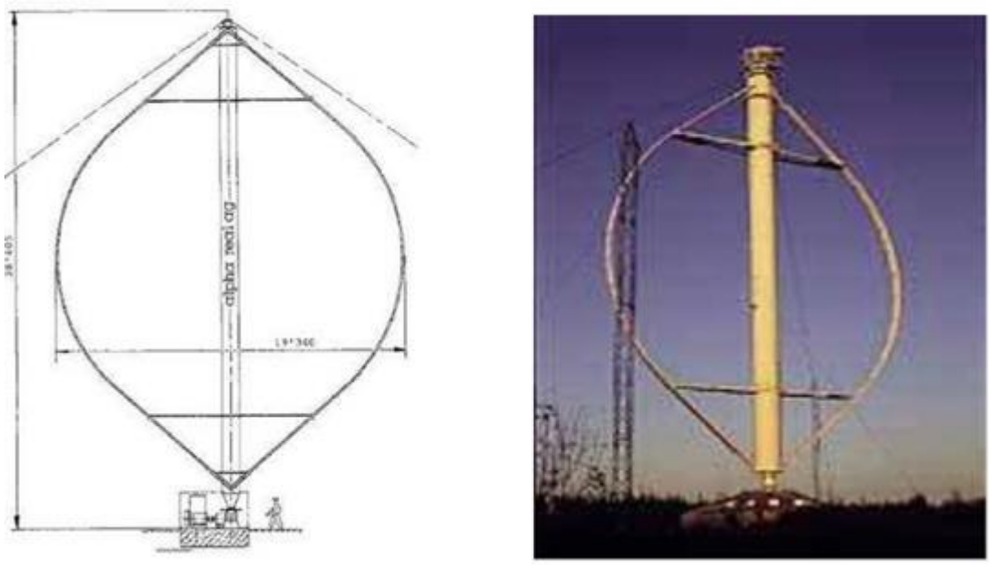


Figure 3.6 : Darrieus Type VAWT

f) Advantages of VAWT:

a) **VAWT** system has lower noise during operation.

b) It may be designed without any starting device.

c) Generator is kept on earth so it is easy to maintain.

d) Do need large space

g) Disadvantages of VAWT:

a) VAWTs may need guy wires to hold it up.

b) They have relative high vibration because the air flow near the ground creates turbulent flow.

c) compared to horizontal axis wind turbines VAWT are very less efficient

3.5 Electricity Generation from Wind Energy:

Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power is converted into electric power using a generator as shown in fig 3.7 below and in block diagram shown in fig 3.8.

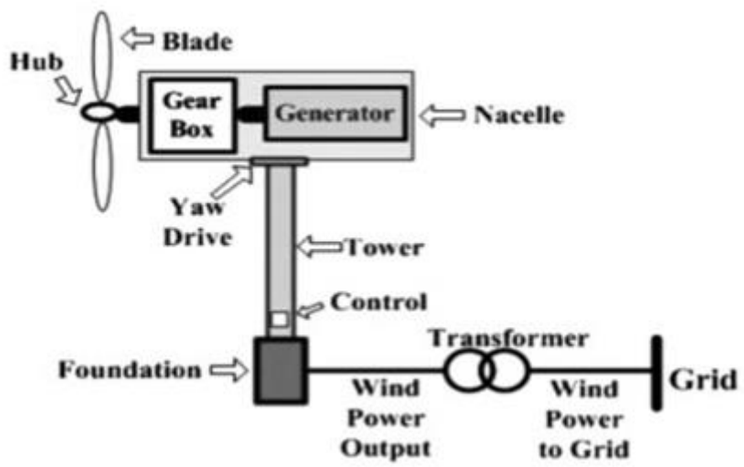


Figure 3.7: Schematic diagram of Electricity generation from wind energy

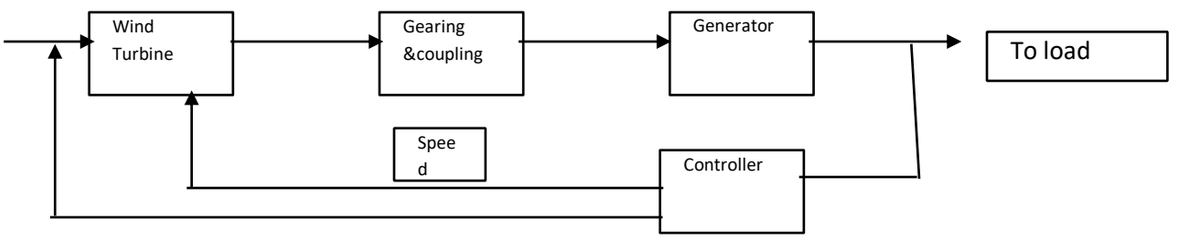


Figure 3.8: Block diagram of Electricity generation from wind energy

3.6 Classification of Wind Power Plants:

1. **Based on the axis of rotation:**
   a. Horizontal Axis wind turbine
   b. Vertical Axis wind turbine
2. **Size or Capacity of Plant:**
   a) **Small wind power plant:** These are having a generation capacity of 10 to 50 Kw having rotor diameter of wind turbine 1 to 15m.
   b) **Medium wind power plant:** These are having a generation capacity of 50 to 500 Kw having rotor diameter of wind turbine 15 to 50m.

c) **Large wind power plant :** These are having a generation capacity of 50MW to 150 MW

3. According to Power Output:

a) **D.C Wind power plant**

b) **A.C wind power plant**

4. According to speed:

a) **Constant speed wind power plant**

b) **Variable speed wind power plant**

5. According to utilization:

a) **Directly connected to load**

b) **Battery storage**

c) **Grid connected system**

4.7 Selection of site for a wind power plant:

a) Plant must be away from city and forest area.

b) Plants are always installed in flat area because wind velocity is high in this area.

c) Cost of land for the site should be minimum as possible

d) High annual average wind speed

e) Availability of anemometry data

f) Altitude of the proposed site

g) Nearness of site to local centre/users

3.8 **Energy Storage**:

Wind turbine operation is not reliable at very high cost and very low speed. The power has low demand, excess wind energy would be stored for use at other time.

Wind energy can be stored by:-

a) Battery:

There are three important types of large-scale BES. These are: lead-acid (LA); nickel-cadmium (NiCd); sodium-sulphur (NaS). These operate in the same way as conventional batteries, except on a large scale, i.e. two electrodes are immersed in an electrolyte, which allows a chemical reaction to take place so current can be produced when required.

b) Flywheel energy storage:

A flywheel energy storage (FES) device is made up of a central shaft that holds a rotor and a flywheel. This central shaft rotates on two magnetic bearings to reduce friction contained within a vacuum to reduce aerodynamic drag losses. Flywheels store energy by accelerating the rotor/flywheel to a very high speed and maintaining the energy in the system as kinetic energy. Flywheels release energy by reversing the charging process so that the motor is then used as a generator. As the flywheel discharges, the rotor/flywheel slows down until eventually coming to a complete stop.

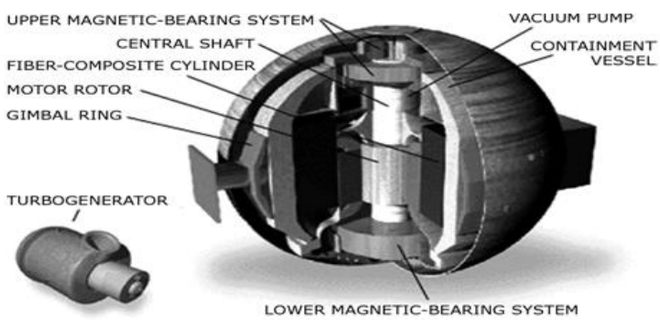


Figure 3.9: Flywheel energy storage device

c) Compressed air storage :

Compressed air energy storage (CAES) systems compress air using electricity during off-peak times, and then store the air in underground caverns. During peak demand, the compressed air from the storage is drawn and fired with natural gas in a combustion turbine to generate electricity. This method uses only a one third of the natural gas used in conventional methods. Because CAES plants require some sort of underground reservoir, they are limited by their locations.

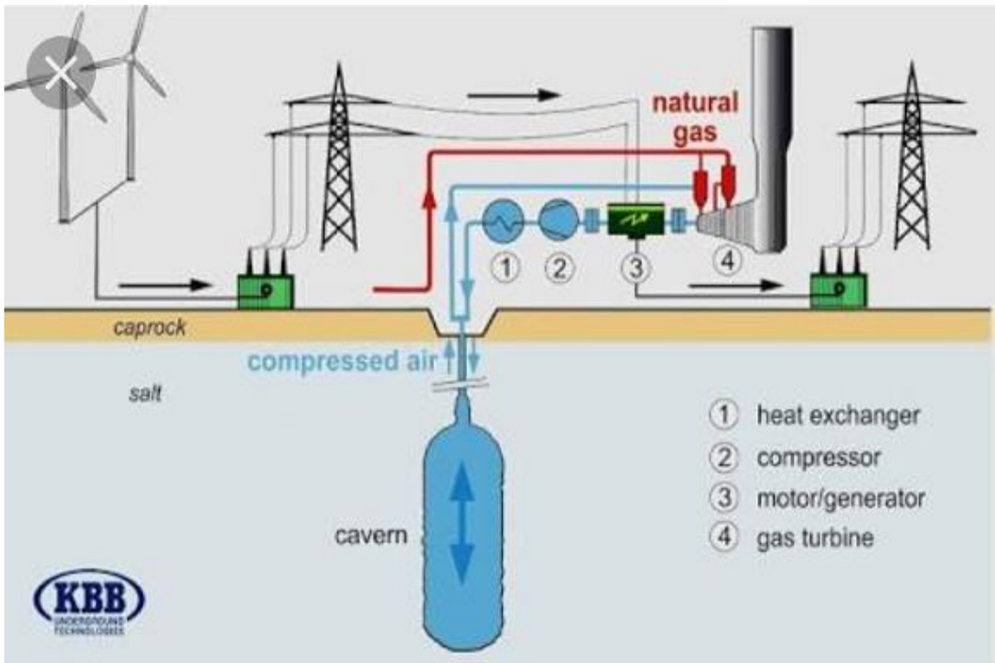


Figure 3.10: compressed air storage system

d) Hydrogen Fuel cell:

Hydrogen fuel cells can also be used to store excess energy. A hydrogen generator is used to electrolyses water using power generated from the wind turbine, storing the resulting hydrogen and converting it back to electricity using a fuel cell power system when needed.

CHAPTER-3.2

GEO-THERMAL AND TIDAL ENERGY

3.2.1 Geo-Thermal Energy:-

The word geothermal comes from the Greek words geo (earth) and thermal (heat). So, geothermal energy is heat from within the earth.

Energy present in the form of heat in the earth crust is called geo thermal energy. It is renewable source of energy because inner part of earth will continue to heat up.

We can use the steam and hot water produced inside the earth to heat buildings or generates electricity.

Geothermal energy is generated in the earth's core, about 4,000 miles below the surface. Temperatures hotter than the sun's surface are continuously produced inside the earth by the slow decay of radioactive particles, a process that happens in all rocks. The earth has a number of different layers:

- ✓ The core itself has two layers: a **solid iron core** and an outer core made of very hot melted rock, called **magma**.
- ✓ The **mantle** which surrounds the core and is about 1,800 miles thick. It is made up of magma and rock.
- ✓ The **crust** is the outermost layer of the earth, the land that forms the continents and ocean floors. It can be three to five miles thick under the oceans and 15 to 35 miles thick on the continents.

The earth's crust is broken into pieces called **plates**. Magma comes close to the earth's surface near the edges of these plates. This is where volcanoes occur. The lava that erupts from volcanoes is partly magma. Deep underground, the rocks and water absorb the heat from this magma. The temperature of the rocks and water get hotter and hotter as you go deeper underground.

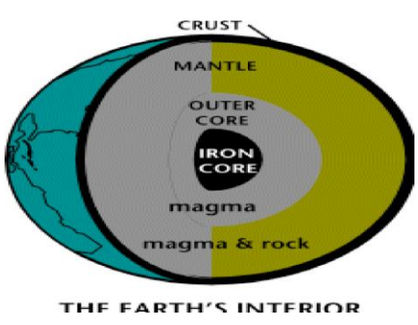


Figure 3.2.1. Earth interior

3.2 Various Geo-Thermal Energy Sources:

a) Hydro thermal convective system

b) Geo pressure resources

c) Hot dry rocks

d) Magma resources

a) Hydro Thermal Convective System:

The word Hydro is related to water and thermal is related to heat. In this system water is heated by its Contact with hot rocks. Thickness of earth crust above magma is 30km.Due to internal earth pressure magma is raised upto an impervious rock above this layer where water has penetrated from a distance. So, water is heated up due to convection. Hence , we collect hot water from earth surface.

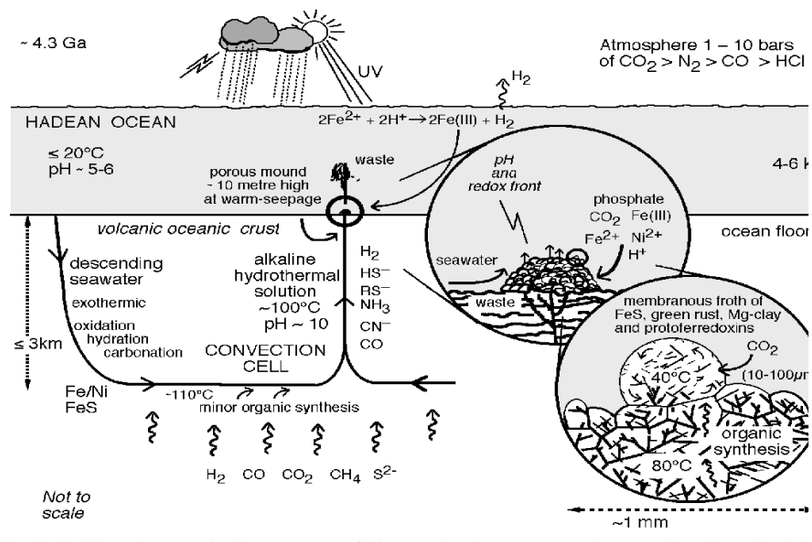


Figure 3.2: Hydro Thermal Convective System

Hydro thermal source are further sub divided into:

i. Vapour dominated system

ii. Liquid dominated system

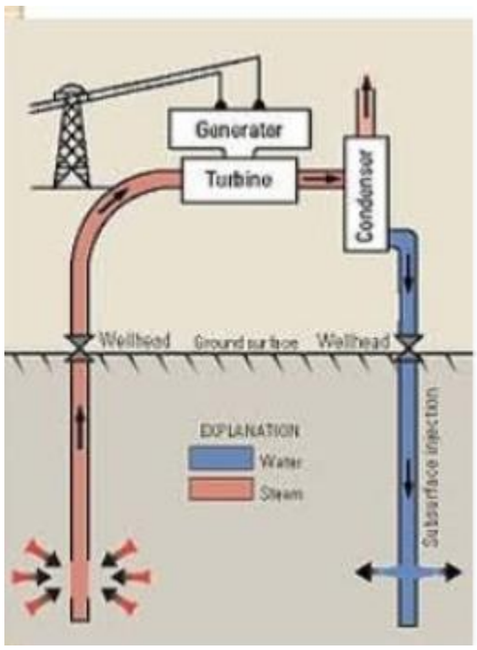
i. Vapour dominated system(Dry steam):

When the geothermal resource produce a saturated or superheated vapor, the steam is collected from the production wells and sent to a conventional steam

turbine as shown in fig 3.3. Before the steam enters the turbine, appropriate measures are taken to remove any solid from the steam flow, as well as corrosive substance contained in the process (typically removed with water washing). Steam after passing through turbine, condenses in the condenser and is re-injected back to the earth.

ii. **Liquid dominated system:**

Liquid dominated power plants are also referred to as flash steam power plants; as they conduct flash steam by pressurizing hot water from the surface of the earth. Such power plants operate using water reservoirs with temperature greater than 360 degree Fahrenheit. These reservoirs are found in specific locations like mantle hot spots, near volcanoes.



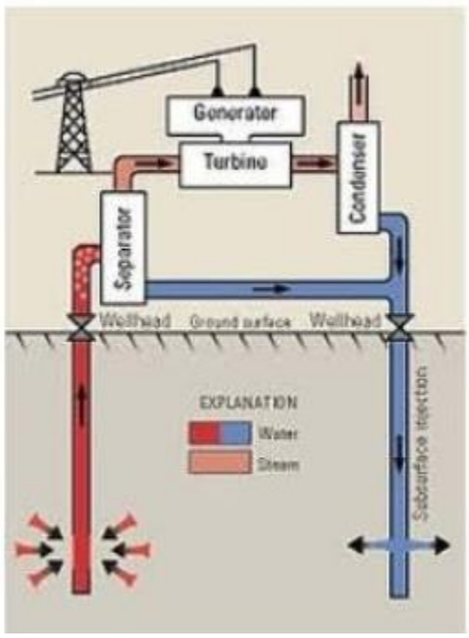


Fig. 3.3:Vapour dominated power plant; Fig 3.4 flash steam power plant

b) **Geo Pressure System**: In this type of reserve, brine completely saturated with natural gas in stored under pressure from the weight of overlying rock. This type of resource can be used for both heat and for natural gas.

c) **Hot Dry Rocks**: The simplest models have one injection well and two production wells. Pressurized cold water is sent down the injection well where the hot rocks heat the water up. Then pressurized water of temperatures greater than 200^0F is brought to the surface

and passed near a liquid with a lower boiling temperature, such as an organic liquid like butane. The ensuing steam turns the turbines. Then, the cool water is again injected to be heated. This system does not produce any emissions. US geothermal industries are making plans to commercialize this new technology.

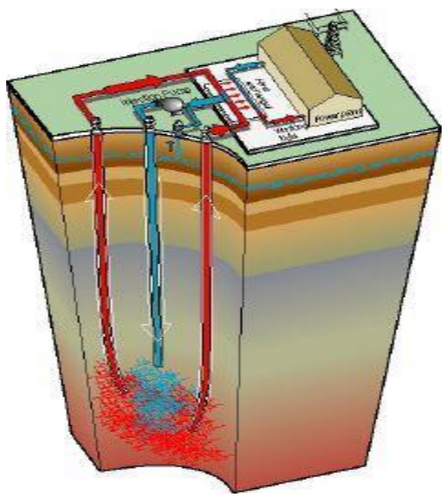


Fig 3.5 Hot Dry Rock

d) Molten Magma: No technology exists to tap into the heat reserves stored in magma. The best sources for this in the US are in Alaska and Hawaii

3.3 Prime Mover for Geo-Thermal Energy Conversions:-

Prime mover is also called turbine. A machine that converts the kinetic energy of steam into mechanical energy is called turbine or prime mover

Prime mover can be classified:

a) Impulse turbine

b) Reaction turbine

a) **Impulse turbine: -**

It is a turbine the total pressure of steam converted into kinetic energy by nozzle. The kinetic energy derives a wheel turbine

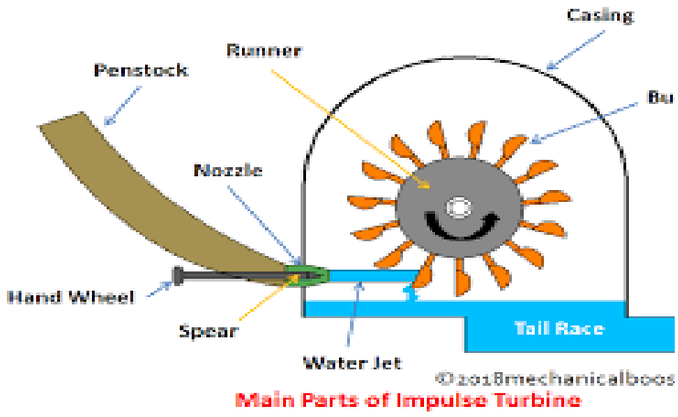


Figure 3.6 Impulse Turbine

b) **Reaction Turbine:**

In reaction turbine steam enter with partly pressure and velocity into turbine.

They are several types: - Francis turbine, Kaplan turbine

3.4 Power Generation by Geo Thermal Resources:-

Figure 3.7 Power Generations by Geo Thermal Resources

3.5 Advantage and disadvantages of Geo-Thermal energy:-

- **Advantages:-**

i. Small Maintenance Cost

ii. Brilliant Efficiency

iii. Highly Sustainable

iv. Increase in Employment

v. Reduction in Noise Pollution

vi. It is More Reliable

vii. It Saves the Non-renewable Fossil Fuel Sources

- **Disadvantage**

i. Environmental Issues. There is an abundance of greenhouse gases below the surface of the earth, some of which mitigates towards the surface and into the atmosphere.

ii. Surface Instability (Earthquakes)

iii. Expensive

iv. Location Specific

v. Sustainability Issues

3.6 Application of GEO-THERMAL energy:

We can use the steam and hot water produced inside the earth to heat buildings or generates electricity. Geothermal energy is a renewable energy source because the water is replenished by rainfall and the heat is continuously produced inside the earth.

Q.1 **Which of the following is the energy used for storing Wind energy?**

a) Kinetic b) Potential

c) Chemical d) Electrical

Q.2 **Wind turbines are of ____ types.**

a) 2 b) 4

c) 6 d) 8

Q.3 The power generated by an horizontal type wind turbines for basic applications is _____.

a) Less than 100kW b) 100 kW

c) 1000kW d) greater than 1000kW

Q.4 **Which of the following is the function of HAWTs in gearbox of horizontal wind turbine?**

a) Speeds up the rotation of blades b) Slows down the rotation of blades

c) Maintains speed of blades d) none

Q.5 **What is the height of HAWT tower?**

a) 40 to 100 meters b) 50 meters

c) 110 meters d) 30 meters

Q.6What is hot molten rock called?

a) Lava

B)Magma

c)Igneousrocks

d) Volcano

Q.7 How much is the efficiency of geothermal plant?

a) 28% b) 15%

c) 48% d) 30%

Q.8 Earth's outer layer rock is called as _____

a) Mantle b) Crust

c) Outer core d) Asthenosphere

Q.9 How much is the average temperature at depth of 10 km of earth surface?

a) 200°C b) 900°C

c) 650°C d) 20°C

Q.10 A geothermal solution containing appreciable amounts of sodium chloride or other salts is called as _____?

a) Fluids b) Brine

c) Solvent d) Magma

1a.2. 2 3.a 4.a 5. A 6.b 7. B 8. B 9.a 10.b

UNIT- 4

TIDAL ENERGY AND MHD

4.1 Ocean Energy:-

Energy can be obtained from ocean is called ocean Energy. Approximately 70% area the earth is covered by the ocean. Ocean sources are:

a) Ocean thermal energy conversion

b) Tidal energy

c) Wave energy

i. **Ocean thermal energy conversion(OTES)**:

Solar energy is energy from the sun that is absorbed by the water of ocean according to Lambert law of absorption .It state that each layer of equal thickness of water absorbs the same fractions of light that passes through it.

- **Ocean Thermal Energy Conversion Cycle**

i. **Open cycle system**

ii. **Close cycle system**

iii. **Hybrid cycle system**

i. Open cycle system

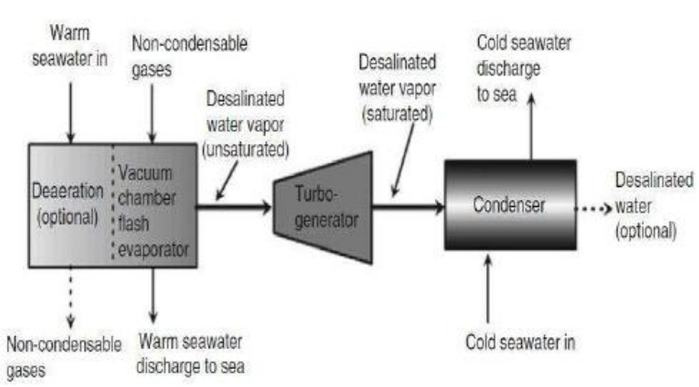


Figure 4.1 OTES open cycle system

ii.

iii.

iv. Closed cycle system

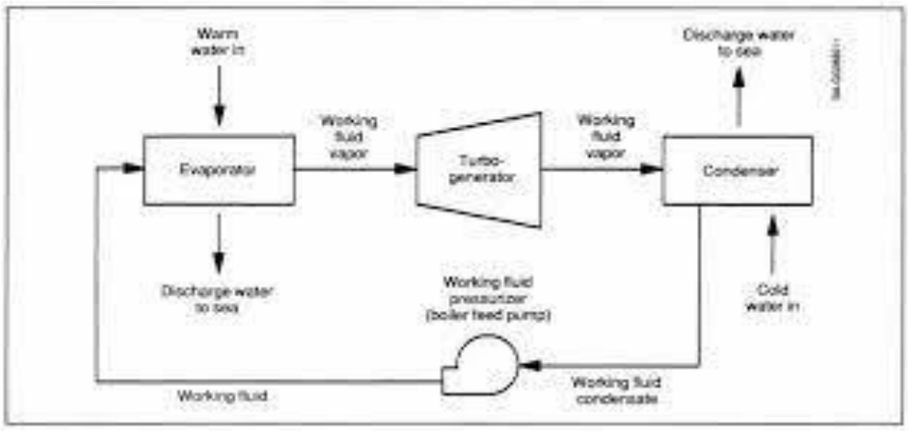


Figure 4.2OTES closed cycle system

v. Hybrid cycle

It is a combination of closed cycle and open cycle system. Warm sea water evaporated in the evaporator ammonia pass through turbine. In a hybrid system, warm seawater enters a vacuum chamber where it is flash-evaporated into steam, similar to the open-cycle evaporation process. The steam vaporizes a low-boiling-point fluid (in a closed-cycle loop) that drives a turbine to produces electricity. The steam condenses within the heat exchanger and provides desalinated water.

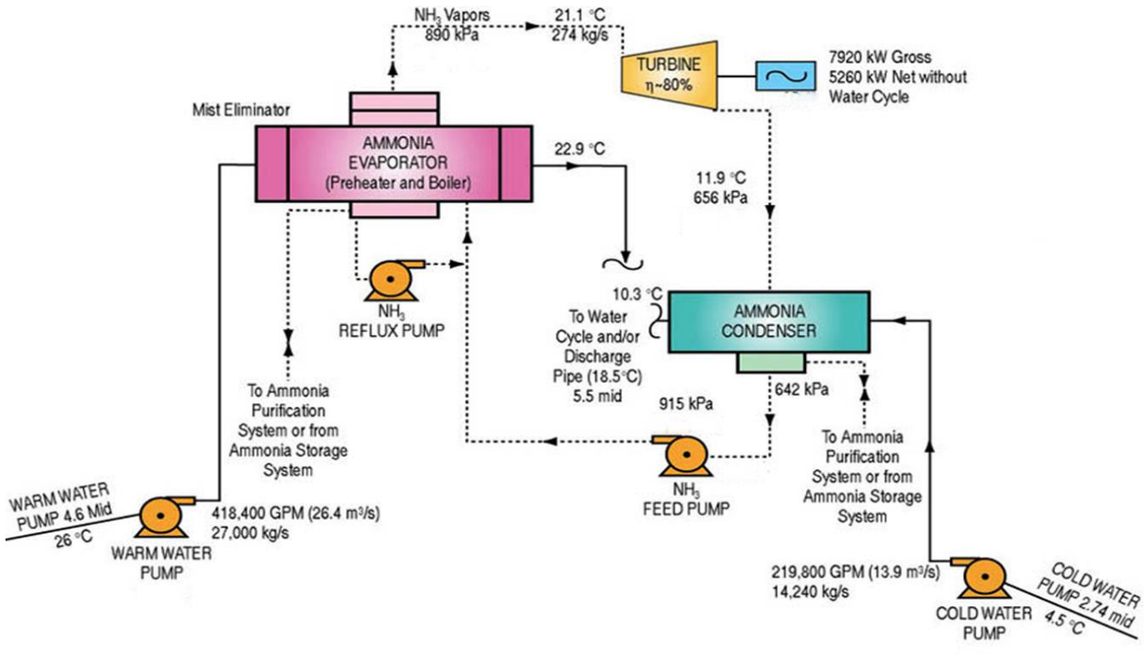


Figure 4.3 OTES Hybrid cycle system

- **Advantages and limitations of OTES system:**

  - **Advantages**

    i. It is renewable sources of energy

    ii. No fuel is used

    iii. OTES systems more economical

  - **Limitations**

    i. Steam has low pressure so large size of turbine required

    ii. Less efficiently

    iii. Overall cost is high

- **Application of OTES**

  i. Chemical treatment plant

  ii. For electricity generation

  iii. Hydrogen production by means of electrolysis

ii. Tidal Energy

Tides in the sea are the result of gravitational effect of heavenly bodies like sun and moon on the earth. Due to fluidity of water mass the effect of this force becomes apparent in the motion of water which slows the periodic change in level.

Working of Tidal power plant:

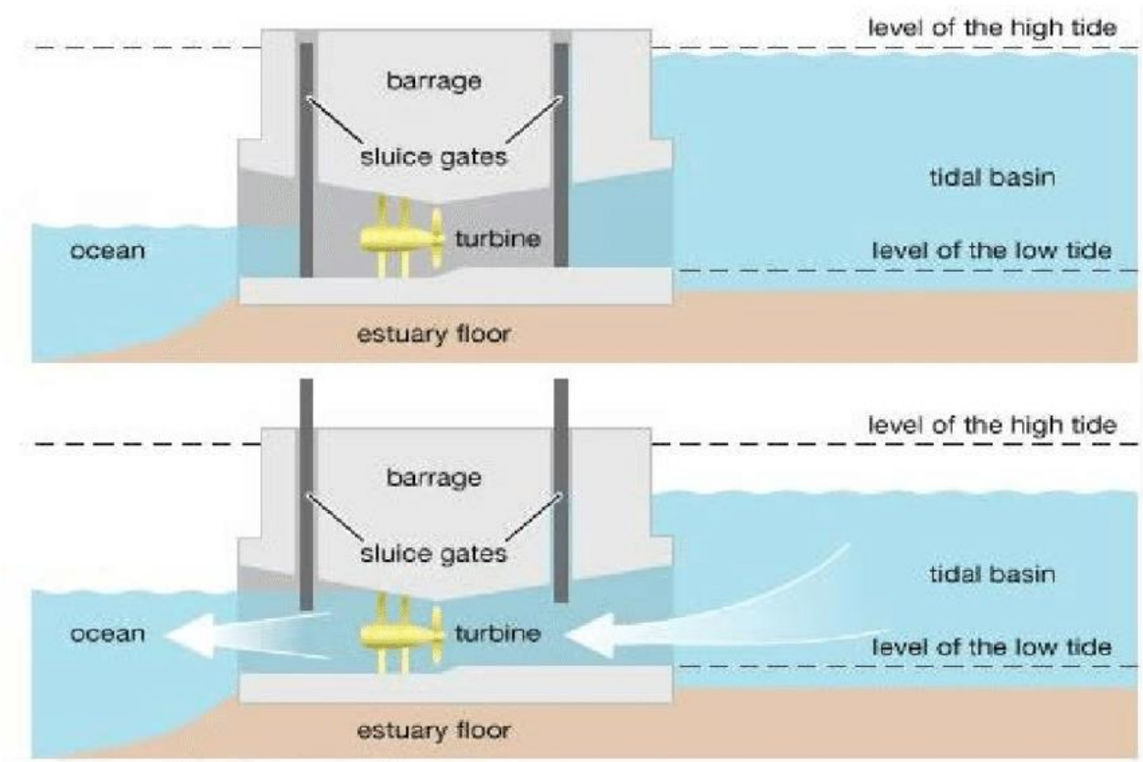


Figure 4.4Tidal Power plant

❖ **Advantage of Tidal energy**

i. Free from pollution

ii. Free mood of nature

iii. Free from disturbing the eco system

❖ **Limitations of Tidal energy:**

i. High initial cost

ii. Sea water is corrosive

iii. Output is not constant it varies with tides.

iv. Conversion device is complicated

iii.

iv. Waves Energy:

Energy is obtained from waves of ocean in the form of kinetic energy depend upon the shape of wave. The waves are generated by strong winds blowing across the sea. Wave energy would be a viable proposition only where waves are very strong. A wide variety of devices have been developed to trap wave energy for rotation of turbine and production of electricity.

Magneto Hydro Dynamic (MHD)

Power Generation

4.2.1 Magneto Hydro Dynamic:

Magneto hydro dynamic is a technique in which heat is directly converted into electricity. It is based on Faraday's law of electromagnetic induction. But it produces only DC power.

- **Working of MHD generator**:

It works on Faraday's law of electromagnetic induction when a magnetic field changes across a conductor an emf is induced in it which produce a electric current this is also the principle of generator.

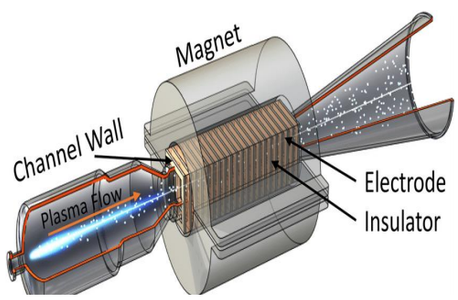


Figure 6.1: MHD Generator

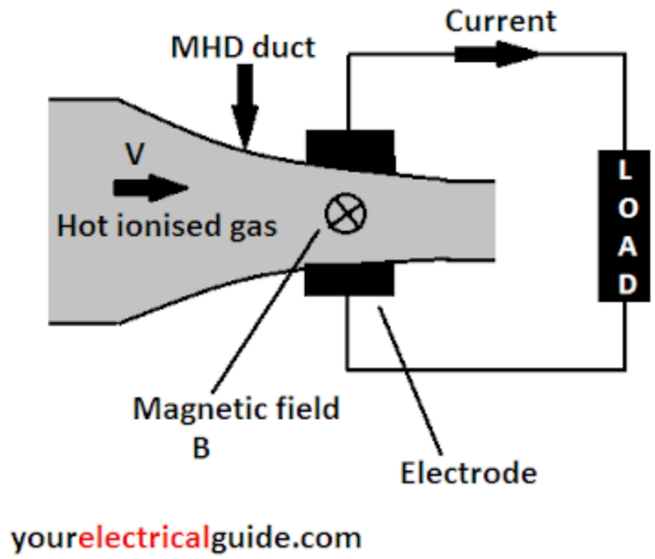


Figure 6.2 Electrical Equivalent circuit of MHD

- **Advantages and disadvantages of MHD**

  - ✓ **Advantages:-**

    i. Efficiency of MHD generator is around 60%

    ii. It generate large amount of power

    iii. It is renewable source of energy

  - ✓ **Disadvantages:-**

    i. There is problem of availability of conducting Gas or any other fluid.

    ii. Difficult to fabricate MHD generator

6.2 Types of MHD generation system

a) Open cycle MHD power generation system

b) Closed cycle MHD power generation system

a) Open cycle MHD power generation system:

Combustion chamber burns the fuel in presence of O_2 at 1000°C. This hot and pressurized fluid ionize the gas. Then gas is passed through a nozzle to increase its velocity.

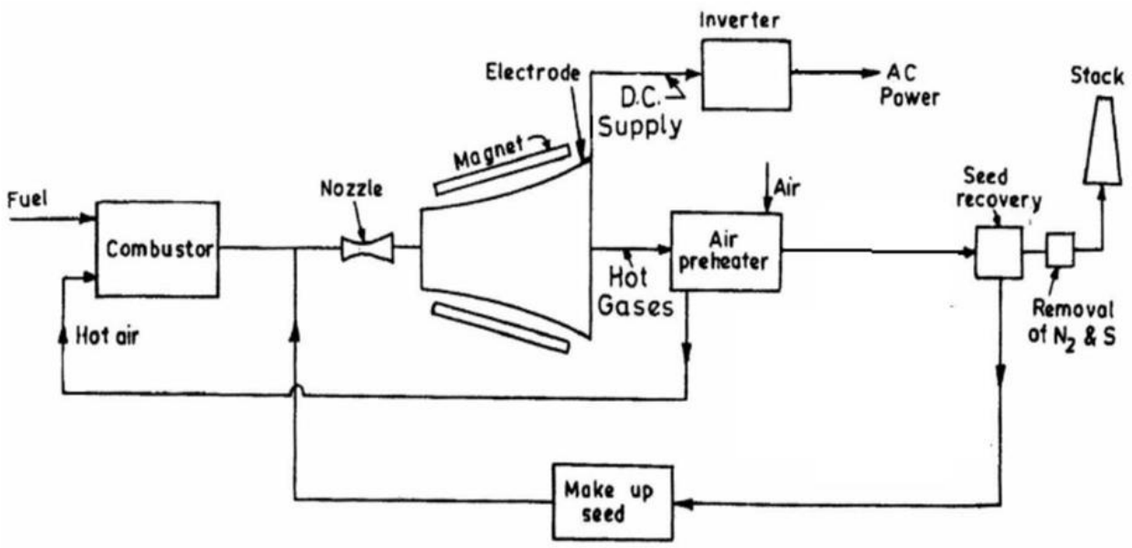


Figure 4.3: Open cycle MHD power generation system

b) Closed cycle power generation system:

In closed cycle MHD system conducting fluid is used again and again to form a closed cycle instead of exhausting the fluid in atmosphere.

Combustor and heat is used to heat the argon or helium gas at 1900°C.This gas is slowed down by diffuser and cool into pre cooler.

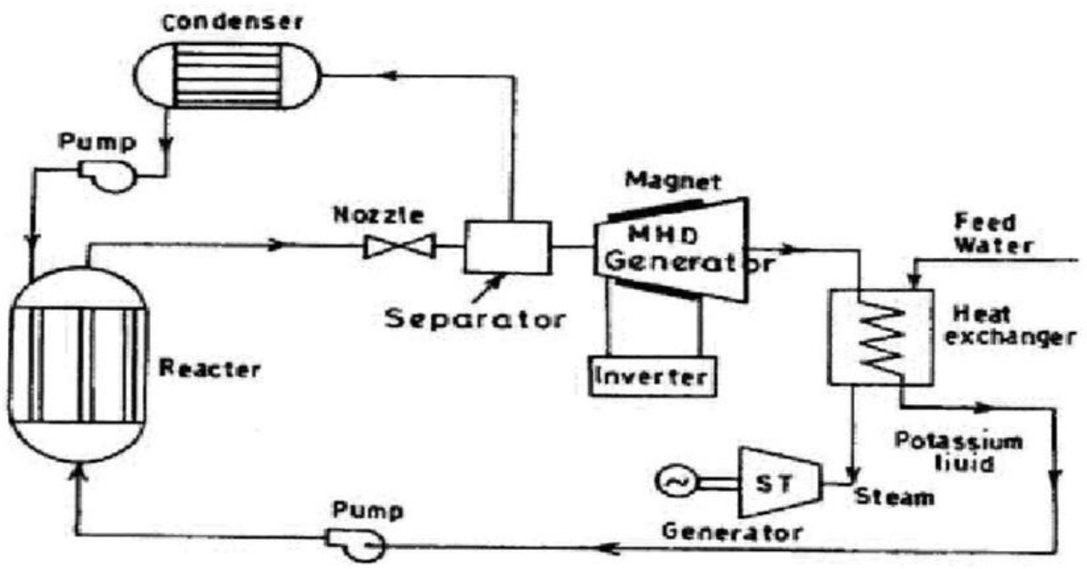


Figure 4.3: Closed cycle MHD power generation system

4.3 Application of MHD

a) Power generation in space craft.

b) Hypersonic wind tunnel experiments.

c) Defense application.

MCQ

Q.1 Which of these materials are not used for MHD duct walls?

a) magnesium oxide b) strontium zirconate

c) hafnia d) magnesium zirconate

Q.2 MHD works on the principle of

a) Faradays law b) Magnetic induction law

c) chemical law d) none

Q.3 To reduce the power consumption of electromagnets, which type of coils have been suggested?

a) aluminium b) high temperature resistant

c) cryogenic & superconducting d) none of the mentioned

Q.4 The output power of MHD is

a) AC b) DC

c) both d) none

Q.5 Working fluid in closed cycle MHD system is

a) coal b) helium and argon

c) Natural gas d) none

Q.6 Tidal plant can be only ……..supply of power

a) high b) low c) uneven d) none

Q.7 Which of the following categories does tidal power fall into?

a) Hydrothermal b) Hydropower

c) Solar d) Wind

Q.8 What is/are the cause(s) of tides?

a) Gravitational pull of moon

b) Gravitational pull of moon and sun

c) Gravitational pull of sun and moon and rotation of earth

d) Gravitational pull of sun

Q.9 What is the minimum height of tides required for harnessing tidal energy economically?

A) 1 feet b) 5feet

c) 10 feet d) 8 feet

Q.10 Which of the following best describes the working of tidal barrage for outgoing tides?

a) Generator → basin → ocean → outgoing tide

b) Generator → ocean → basin → outgoing tide

c) Ocean → generator → basin → outgoing tide

d) Outgoing tide → generator → basin → ocean

1.a 2.a 3.c 4.b 5.b 6.b 7.b 8.c 9.c 10.d

CHAPTER-5

FUEL CELLS

5.1 Fuel Cell:

A fuel cell is like a battery in that it generates electricity from an electrochemical reaction. Both batteries and fuel cells convert chemical energy into electrical energy and also, as a by-product of this process, into heat.

Fuel cells can produce electricity continuously for as long as fuel and oxygen are supplied.

5.2 Design and operation Principal of fuel cell:

For any type of fuel cell, there are mainly following segments

a) Two electrode(anode, cathode)

b) Electrolyte that separates the two electrodes is an ion conducting material which facilities the free passage of ions.

The electrolyte used depends upon the types of fuel cell .Whatever the type of fuel cell their basic operation is always same.

At anode (an oxidation reaction):

At anode-catalyst (mainly platinum powder) oxidizes the hydrogen fuel and turning the fuel into positively charged ion and negatively charged electron.

$$2H_2 \longrightarrow 4H^+ + 4e^-$$

Out of these, the ions make way through the electrolyte to the cathode.

At cathode (a reduction reaction):

As soon as they reach the cathode, they combine with the oxidant (oxygen) and then react with the oxidant to produce water.

$$O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$$

Overall reaction:

$$2H_2 + O_2 \longrightarrow 2H_2O$$

The electrons pass through a wire producing the electricity. Nickel is mostly used as the cathode catalyst. Thus the electricity is formed at the load and water is obtained as the by-product.

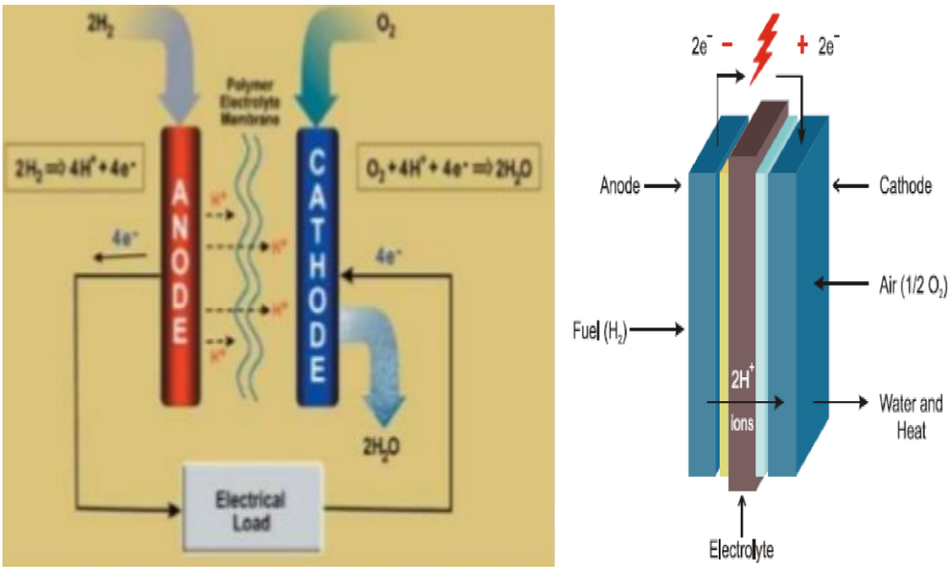


Figure 5.1: Generic Hydrogen Fuel Cell Operation

Though a fuel cells generate only small DC voltages (0.7 volts) at full load, which are then combined in series to achieve substantial voltage and power capacities.

Fuel cells differ from batteries in the nature of their anode and cathode. In a battery, the anode and cathode are metals; zinc or lithium is typically used for the anode and metallic oxides for the cathode. In a fuel cell, the anode and cathode are composed of gases often in contact with a platinum catalyst to promote the power generating reaction. Hydrogen or a hydrogen-rich gas mixture is typically used as the anode and oxygen or air as the cathode.

5.3 Types of Fuel cells:

Fuel cell types are generally classified according to the nature of the electrolyte they use. Each type requires particular materials and fuels and is suitable for different applications.

i. Hydrogen oxygen fuel cell
ii. Alkaline fuel cell- alkaline solution electrolyte such as KOH.
iii. Phosphoric acid fuel cell (PAFC): electrolyte is phosphoric acid.
iv. Solid Proton Exchange Membrane Fuel cell: Electrolyte is polymer electrolyte membrane fuel cells and their electrolyte consists of the proton exchange membrane.
v. Molten carbonate Fuel cells: electrolyte as molten carbonate
vi. Solid oxide fuel cell(SOFC): electrolyte is ceramic ion conducting electrolyte in solid oxide form

vii. Direct methanol fuel cell

All fuel cells are based around a central design using two electrodes separated by a solid or liquid electrolyte that carries electrically charged particles between them. A catalyst is often used to speed up the reactions at the electrodes.

5.4 Conversion efficiency of Fuel cell:

Fuel cell efficiency is described as the ratio of the electrical energy produced to the heat that is produced by burning the fuel.

From the basic definition of efficiency: $\eta = W / Qin$

Energy produced by 1 mole of liquid water from hydrogen and oxygen gases is 56.67 kcal at room temperature whereas heat energy of the reaction under the same condition is 68.26Kcal.

%age $\eta = (56.67/68.26) *100= 83\%$

Theoretical efficiency of conversion of heat energy into electrical energy in a hydrogen-oxygen fuel cell is 83%. But practically efficiency of pure hydrogen-oxygen fuel cell in the range of 50 to 60%.

5.6 Advantages and Disadvantages of Fuel Cell:

- **Advantages:**

a) Renewable Energy source
b) High Efficiency- when utilizing co-generation, fuel cells can attain over 50 to 60 % energy efficiency
c) Good reliability- quality of power provided does not degrade over time.
d) Noise- offers a much more silent and smooth alternative to conventional energy production.
e) Environmentally beneficial- greatly reduces CO2 and harmful pollutant emissions.
f) Size reduction- fuel cells are significantly lighter and more compact
g) Low Maintenance
h) Simple and safe
i) Static device , no moving parts
j) Light weight

➢ **Disadvantages of Fuel Cells:**

Fuel cell systems suffer the following disadvantages:

a) Hydrogen is currently very expensive, not because it is rare, but because it's difficult to generate, handle, and store, requiring bulky and heavy tanks.

b) Very high capital cost.

c) Technology of fuel cell is under development and not available to all countries.

d) Fuel cells require relatively pure fuel, free of specific contaminants. These contaminants include sulfur and car-bon compounds, and residual liquid fuels (depending on the type of fuel cell) that can deactivate the fuel cell catalyst.

e) Fuel cells require complex support and control systems.

f) Fuel cell systems are heavy. Fuel cells themselves are not excessively heavy, but the combined weight of the fuel cells, their support systems and their fuel storage is presently greater than for a comparable internal combustion engine system.

5.7 Applications:

a) Stationary Power plants: It is adequate to service isolated neighborhoods or to provide emergency backup power to critical facilities, such as hospitals.

b) Submarines: Fuel cells systems are attractive for military submarine applications due to their low noise and infrared signatures. In many ways, fuel cells are a logical replacement for the banks of batteries currently used to power many submarines.

Fig. 5.2: Submarine Fuel Cell Power plant

c) **Vehicles :**

- ✓ Buses are the most commercially advanced of all fuel cell applications to date.
- ✓ Cars represent the ultimate market for fuel cell manufacturers due to the quantities involved worldwide. Some automotive manufacturers have made commitments to introduce fuel cell vehicles to the market in the early years

d) **Portable Power Systems:** Portable fuel cell systems can potentially be used in many applications that currently rely on batteries. Commercial units that provide up to 1.2 kW (4100 Btuh) of electrical power are now available.

Fig.5.3: Portable Fuel Cell Systems

e) They have been used to power many space expeditions

f) These electrochemical cells can also be used to power several electronic devices.

Energy storage : Superconducting Magnetic Energy Storage (SMES) is a novel technology that stores electricity from the grid within the magnetic field of a coil comprised of superconducting wire with near-zero loss of energy. SMES is a grid-enabling device that stores and discharges large quantities of power almost instantaneously.

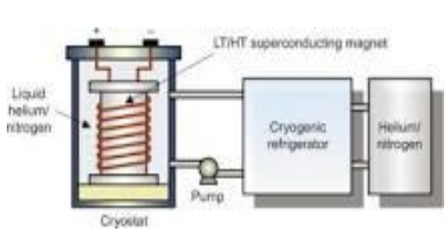


Diagram of Energy storage

Capacitor :

A capacitor is a two-terminal electrical device that can store energy in the form of an electric charge. It consists of two electrical conductors that are separated by a distance. The space between the conductors may be filled by vacuum or with an insulating material known as a dielectric.

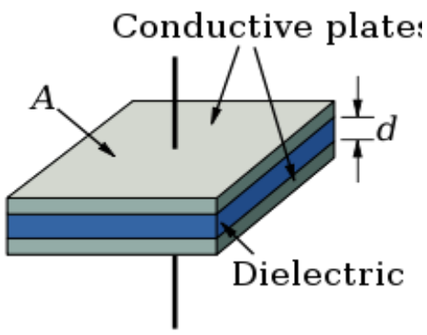
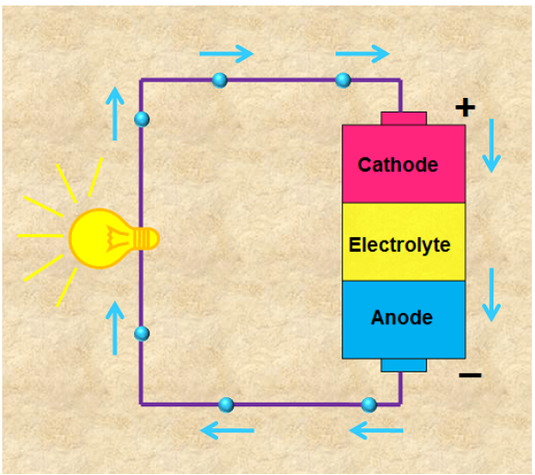
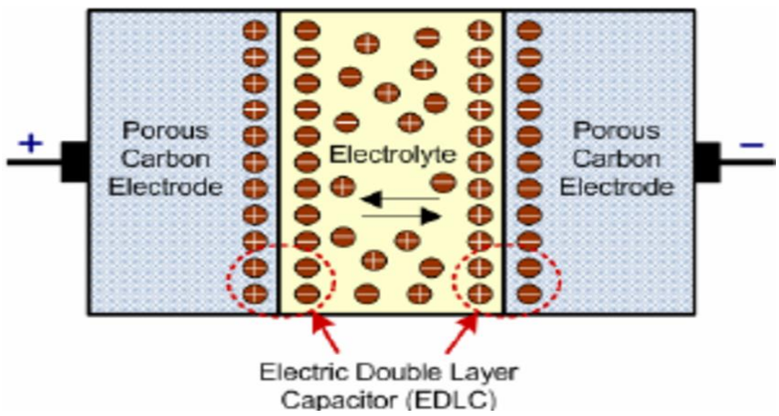


Diagram of Capacitor

Battery: A battery is a source of electric power consisting of one or more electrochemical cells with external connections for powering electrical devices. When a battery is supplying power, its positive terminal is the cathode and its negative terminal is the anode.



Super capacitor : Electrical energy is stored in supercapacitors via two storage principles, static double-layer capacitance and electrochemical pseudocapacitance; and the distribution of the two types of capacitance depends on the material and structure of the electrodes.



Applications of Energy storage :

Energy storage applications are used to meet peak power demands and high power switching in a short time. The peak power supplies are power plants that can be switched on and off for a short time in the traditional structure. It is inevitable to use energy storage applications within advanced power systems

The aforementioned types of the energy storage systems can be categorized into large systems used by power suppliers like energy storage by using pumped hydro, compressed air, hydrogen and flywheels, and smaller systems that can be used for industrial or residential applications like batteries and storage of the energy in the form of heat, for instance using heat pumps.

.MCQ

Q.1 For satellite the source of energy is…..

a) true b) false

c) none

Q.2 In a fuel cell electrical energy is produced by

a) geothermal b) chemical energy

c) wind energy d) radio –active substances

Q.3 Fuel cell have conversion efficiency of about

a) 98% b) 33%

c) 42% d) 65%

Q.4 Electrolytic solution used in a hydro oxygen fuel cell

a) 75% KOH solution b) 25% KOH solution

c) 75% NAOH solution d) none

Q.5 Primary source of energy

a) wood b) wind

c) lakes d) all of these

Q.6 What is voltage output of hydrogen oxygen fuel cell?

a) 1.23 V b) 1.45 V

c) 1.01 V d) .93V

Q.7 For which of the following devices does negative charge carriers flow from anode to cathode in the external circuit?

a) MHD generator b) Thermionic generator

c) thermoelectric generator d) Fuel cell

Q.8 When do we get maximum energy from a set of capacitors?

a) When they are connected in parallel

b) When they are connected in series

c) Both in series and parallel

d) Insufficient information provided

Q.9 Work done in charging a capacitor is _____

a)QV

b) ½QV

c) 2QV

d)QV2

1.a 2.b 3.d 4.a 5.d 6.a 7.d 8.a 9.b