Renewable Energy and Energy Harvesting
SEM4, SEC2T

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SEC-2: Renewable Energy and Energy Harvesting Credits 02

SEC2T: Renewable Energy and Energy Harvesting	Credit 01

Fossil fuels and Alternate Sources of energy

Fossil fuels and nuclear energy, their limitation, need of renewable energy, non-conventional energy sources. An over view of developments in Offshore Wind Energy, Tidal Energy, Wave energy systems, Ocean Thermal Energy Conversion, solar energy, biomass, biochemical conversion, biogas generation, geothermal energy tidal energy, Hydroelectricity.

Solar energy

Solar energy, its importance, storage of solar energy, solar pond, non-convective solar pond, applications of solar pond and solar energy, solar water heater, flat plate collector, solar distillation, solar cooker, solar green houses, solar cell, absorption air conditioning. Need and characteristics of photovoltaic (PV) systems, PV models and equivalent circuits, and sun tracking systems.

Wind Energy harvesting

Fundamentals of Wind energy, Wind Turbines and different electrical machines in wind turbines, Power electronic interfaces, and grid interconnection topologies.

Ocean Energy

Ocean Energy Potential against Wind and Solar, Wave Characteristics and Statistics, Wave Energy Devices.

Tide characteristics and Statistics, Tide Energy Technologies, Ocean Thermal Energy, Osmotic Power, Ocean Biomass.

Geothermal Energy

Geothermal Resources, Geothermal Technologies

Hydro Energy

Hydropower resources, hydropower technologies, environmental impact of hydro power sources.

Piezoelectric Energy harvesting

Introduction, Physics and characteristics of piezoelectric effect, materials and mathematical description of piezoelectricity, Piezoelectric parameters and modeling piezoelectric generators, Piezoelectric energy harvesting applications, Human power

SEC2P: Practical	**Credit 01**

Demonstrations and Experiments

1. Demonstration of Training modules on Solar energy, wind energy, etc.
2. Conversion of vibration to voltage using piezoelectric materials
3. Conversion of thermal energy into voltage using thermoelectric modules.

Contents

Renewable Energy Sources

- Renewable energy is energy produced from sources that do not deplete or can be replenished within a human's life time. The most common examples include wind, solar, geothermal, biomass, and hydropower.
- Renewable Energy Sources
  - Radiant solar energy
    - Solar heating (passive and active), solar power plants, photovoltaic cells
  - Biomass energy
    - Direct: combustion of biomass
    - Indirect: chemical conversion to biofuel
  - Wind energy
  - Hydro energy
  - Geothermal energy

All India installed capacity (IN MW) of power stations as on 31/03/2021

Ownership	Thermal							Grand Total
	Coal	Gas	Diesel	Total	Nuclear	Hydro	RES	
STATE SECTOR	67081.50	7087.35	236.01	74404.86	0.00	27069.50	2395.27	103869.64
PVT SECTOR	76003.00	10598.74	273.70	86875.45	0.00	3493.00	90406.21	180774.66
CENTRAL SECTOR	66210.00	7237.91	0.00	73447.91	6780.00	15646.72	1632.30	97506.93
Total of ALL INDIA	209294.50	24924.01	509.71	**234728.22**	**6780.00**	**46209.22**	**94433.79**	**382151.22**

Relevancy……..

What are the problems with conventional sources?

Fossil fuels:

- ✓ Pollution ⟶ Polluted air, water and land causes many chronic and asthmatic diseases, global warming, draught, change in climate etc.
- ✓ Power ⟶ Plants and animals had been decomposed to fossil fuels in a long time chemical process under an elevated pressure and temperature. This is completely natural process and men can not reproduce this environment. Therefore, the Earth will eventually run out of fossil fuels within the next 50 years as estimated. Then what is after 50-100 years…….?

Nuclear power:

- ✓ Radioactivity

⟶ From the nuclear reactors, some penetrating radiation or particles emission occur which are very harmful for living elements of the Earth,

⟶ Damping cost of the radioactive waste products and remaining parts of the reactors is very high.

Though seawater uranium is effectively inexhaustible, it not considered as "renewable energy sources" for provision of development support.

Difference between Conventional and Non Conventional Energy Sources:

Energy can be defined as the capacity or ability to do work. It plays an important role in our day to day life as it is required in every field like industry, transport, communication, sports, defence, household, agriculture and more. There are plenty of energy sources to get energy. These energy resources can be classified as Conventional and Non-conventional sources of energy. Let us see how they differ from each other!

Conventional sources of energy:

Conventional sources of energy are the natural energy resources which are present in a limited quantity and are being used for a long time. They are called non-renewable sources as once they are depleted, they cannot be generated at the speed which can sustain its consumption rate. They are formed from decaying matter over hundreds of millions of years.

These resources have been depleted to a great extent due to their continuous exploitation. It is believed that the deposits of petroleum in our country will be exhausted within few decades and the coal reserves can last for a hundred more years. Some common examples of conventional sources of energy include coal, petroleum, natural gas and electricity.

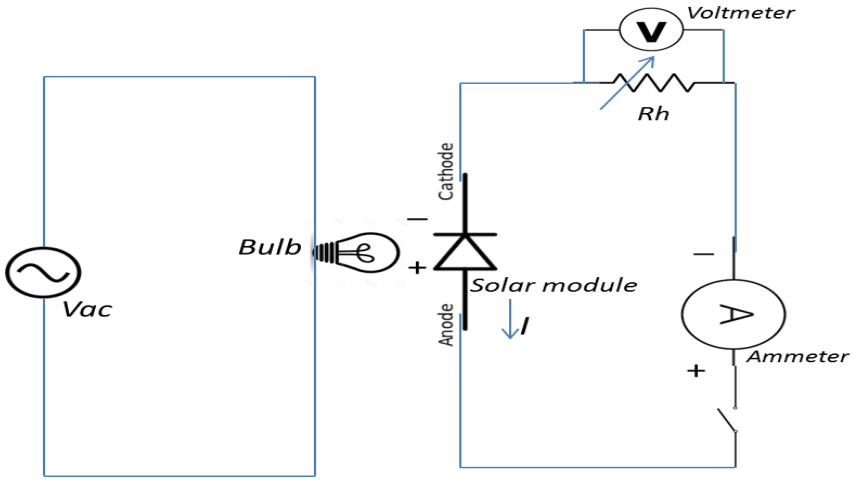
Non-conventional sources of energy:

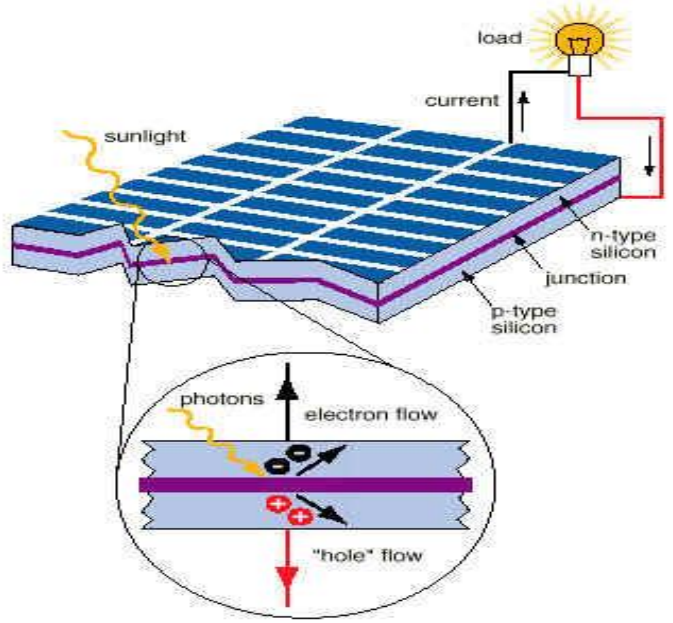
Non-conventional sources of energy are the energy sources which are continuously replenished by natural processes. These cannot be exhausted easily, can be generated constantly so can be used again and again, e.g. solar energy, wind energy, tidal energy, biomass energy and geothermal energy etc. The energy obtained from non-conventional sources is known as non-conventional energy. These sources do not pollute the environment and do not require heavy expenditure. They are called renewable resources as they can be replaced through natural processes at a rate equal to or greater than the rate at which they are consumed.

Conventional sources of energy	Non-conventional sources of energy
These sources of energy are not abundant, present in limited quantity, e.g. coal, petroleum, natural gas.	These sources of energy are abundant in nature, e.g. solar energy, wind energy, tidal energy, biogas from biomass etc.
They have been in use for a long time.	They are yet in development phase over the past few years.
They are not replenished continuously. They are formed over a million years.	They are replenished continuously by natural processes.
They are called non-renewable sources of energy.	They are called renewable sources of energy.
They can be exhausted completely due to over-consumption except for hydel power.	They cannot be exhausted completely.
They pollute the environment by emitting harmful gases and also contribute to global warming.	They are environment-friendly, do not pollute the environment.
They are commonly used for industrial and commercial purposes.	They are used commonly used for household purposes.
Heavy expenditure is involved in using and maintaining these sources of energy.	Using these sources is less expensive.
They are used extensively, at a higher rate than the non-conventional sources.	

Solar cell

Solar cell a semiconductor device which can convert light energy to electric energy.

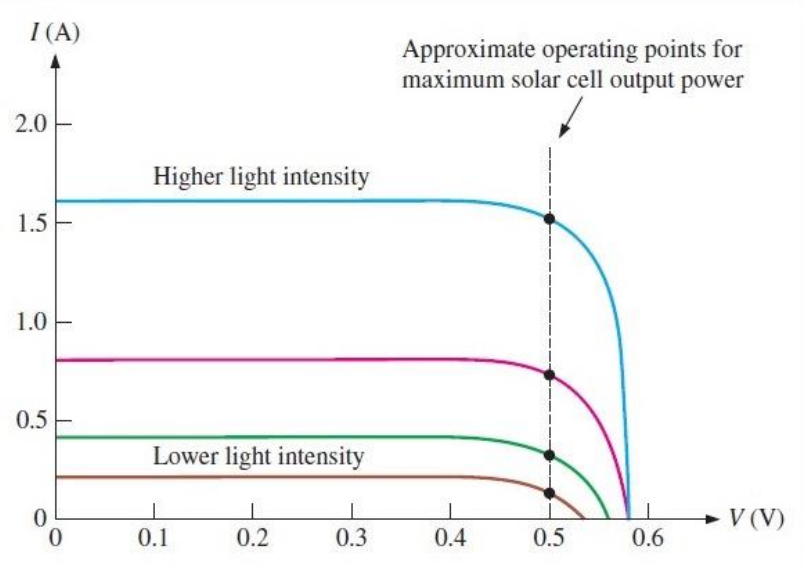




Principles:-

When Photons are incident on the solar cell it reaches to the depletion region and creates the electron-hole pairs. These electrons are moved towards the n-type of cell and holes are moved towards the p-type of the cell. As a result charge imbalance occurs. Now if we connect the n-type side to the p-type side of solar cell by means of an external ckt , current flows through the ckt because this reduces the light induced charge imbalanced in the cell. This effect is called ***photo-voltaic effect.***

Solar cell……

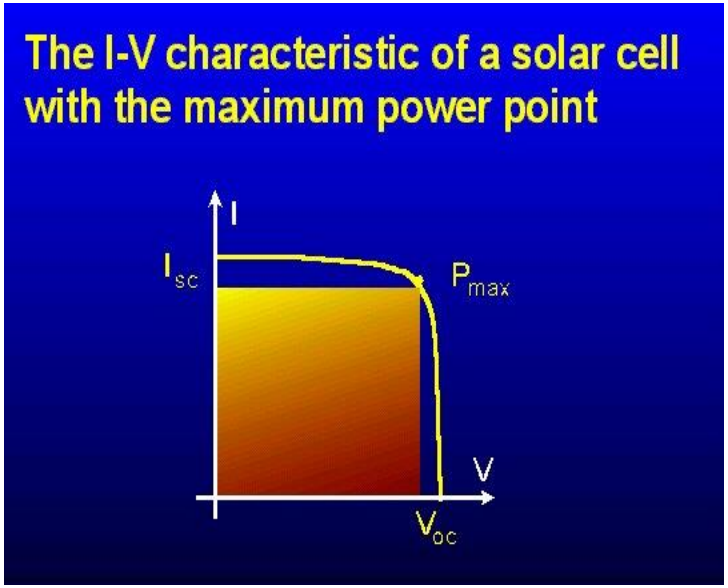


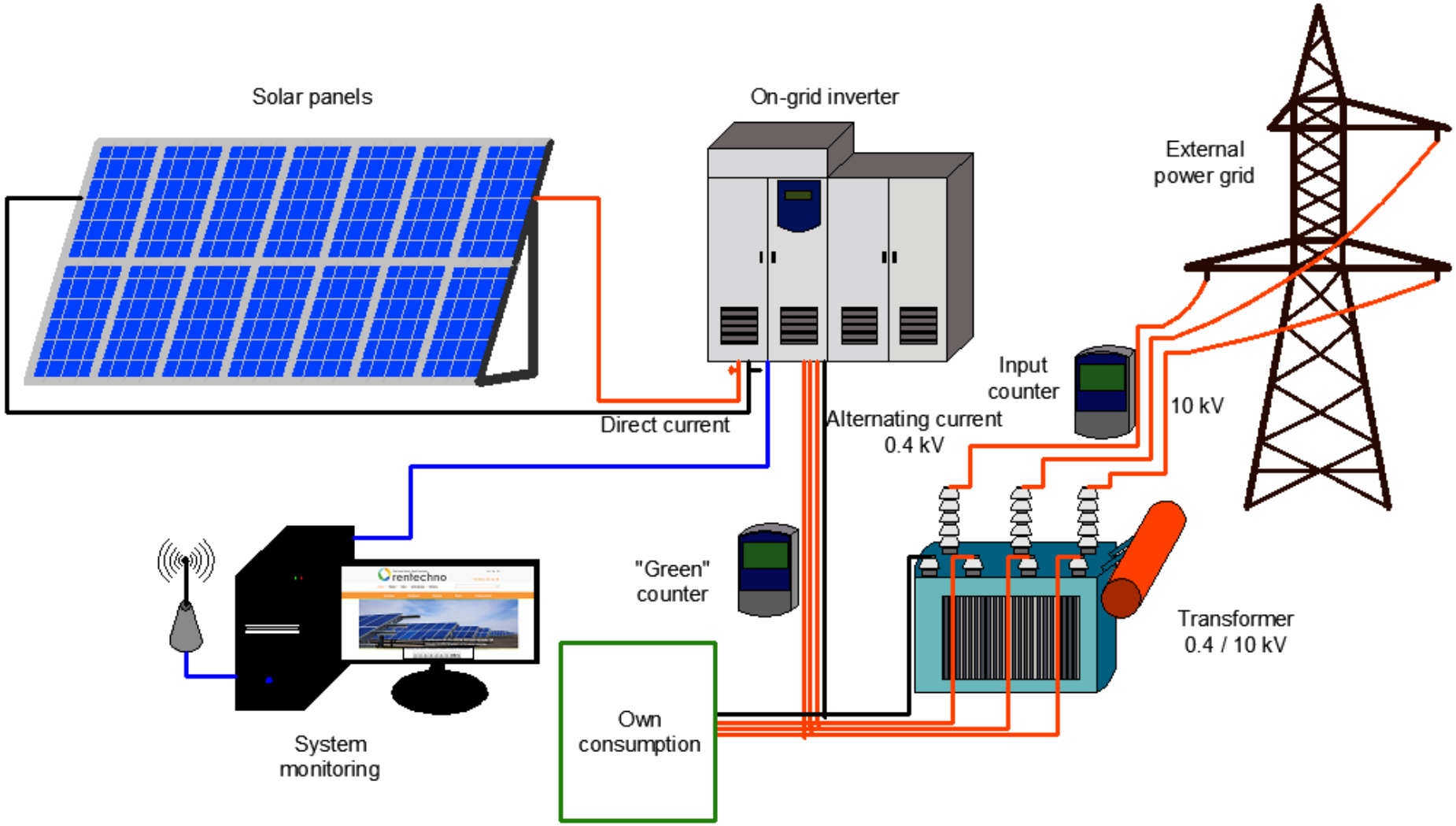
A Picture of experimental setup

- Fill Factor(FF) = $\dfrac{V_m \cdot I_m\ (P_{max})}{V_{oc} \cdot I_{sc}}$

(lies between 0.7 to o.8)

- Conversion Efficiency, $\eta = \dfrac{P_{max}}{P_{in}}$



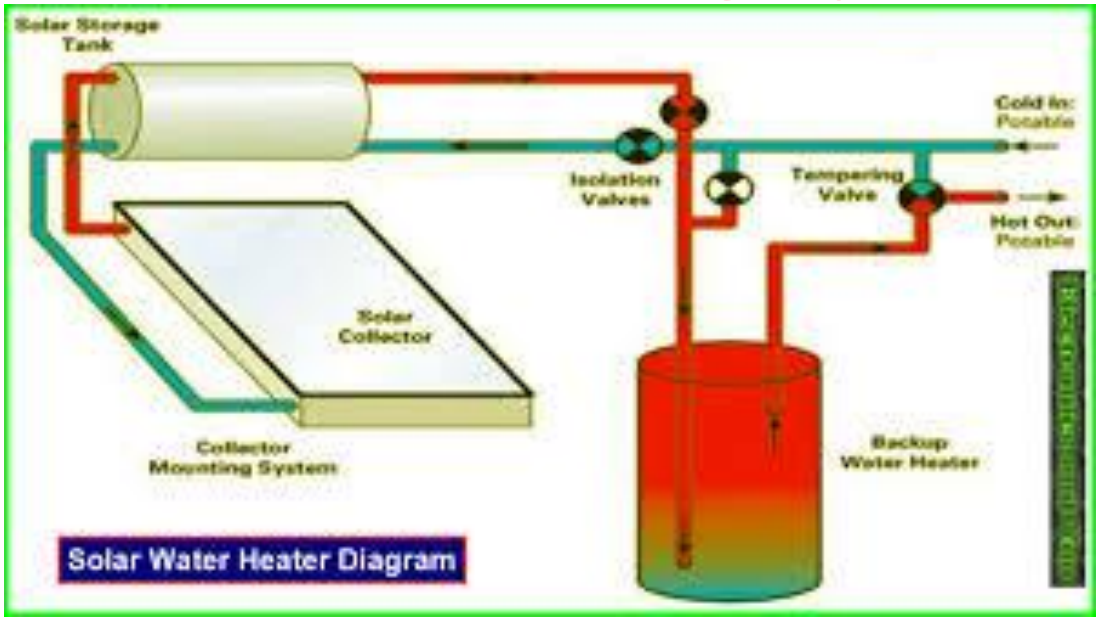


Schematic of 10 kW SPV Plant

Initial Capital Investment for SPV

Components	Value in Lakhs per MW AC
Land	25.00
Modules	330.00
Civil and General Works	55.00
Mounting Structures	40.00
Inverters	40.00
Electricals – Cables Transformers etc.	65.00
Grid Extension and Bay Extension	40.00
Preliminary Expenses, approvals, land levelling etc.	15.00
Total Capital Investment	Rs. 610 Lakhs/MW

Solar Water Heating System



- The system is generally installed on the roof or open ground, with the collector facing the sun and connected to a continuous water supply.
- The collector usually comprises copper tubes welded to copper sheets (both coated with a highly absorbing black coating) with a toughened glass sheet on top and insulating material at the back. The entire assembly is placed in a flat box.
- Water flows through the tubes, absorbs solar heat and becomes hot.
- The heated water is stored in a insulated tank for further use.

Hydro Energy

Advantages:

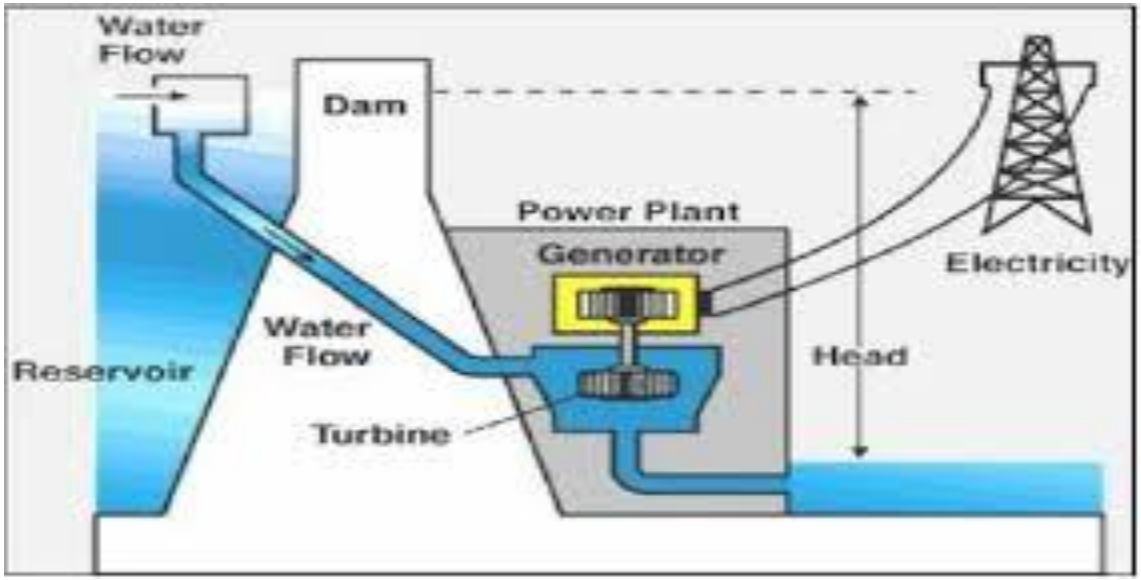
- It does not cause any pollution
- It is a cheap and renewable source of electricity which will never get exhausted.

Disadvantages:

- Human population displacement.
- The soil in the down stream becomes poor in quality.

Hydro Energy

- In hydroelectric power station, the flowing water is stopped in high altitude rivers by constructing dams and is stored in huge reservoir behind the dam. The water stored possessed very large amount of potential energy. Then the water is allowed to fall through pipes on the blades of big water called turbines. These turbines are connected to electric generators.
- Name of few Hydroelectric power plant in India are as, Tehri Dam, Uttrakhand, 2400 MW; Sardar Sarovar Dam, Gujarat, 1450 MW; Bhakra Nangal Dam, Himachal Pradesh, 1325 MW; Purulia Pass, West Bengal, 900 MW; Nagarjuna Sagar Dam, Andhra Pradesh, 960 MW, Hirakudh Dam, Orissa, 500 MW; etc.



Working Principle of Wind Turbines

- Wind turbines work on a simple principle: instead of using electricity to make wind—like a fan—wind turbines use wind to make electricity.
- The energy in the **wind** turns two or three propeller-like blades around a rotor. The rotor is connected to the main shaft, which spins a **generator** to create electricity.
- The **wind** systems that exist over the earth's surface are a result of variations in air pressure.

- Advantages
  - High net energy yield
  - Renewable and free
  - Very clean source of energy
    - No pollution (air or water) during operation
  - Long operating life
  - Low operating/maintenance costs
  - Land can be used for other purposes
    - Can combine wind and agricultural farms
- Disadvantages
  - Energy storage issues
    - An intermittent source of energy; need backup (eg stored energy) for low-wind days
    - Or must be connected to the electrical grid
  - Only practical in areas that are windy enough

Windmill Park at Kanyakumari District of Tamilnadu

Biomass Energy

- What is it?
  - Biomass energy is the use of living and *recently* dead biological material as an energy source
  - Ultimately dependent on the capture of solar energy and conversion to a chemical (carbohydrate) fuel
  - Theoretically it is a *carbon neutral* and renewable source of energy
- How it works?
  - Traditional: forest management, using wood as fuel
  - Use of biodegradable waste
    - Examples: manure, crop residue, sewage, municipal solid waste
  - Production of a liquid or gaseous ***biofuel***
    - *Biogas* due to the breakdown of biomass in the absence of O_2
      - Includes capture of landfill methane
    - *Bioethanol* from fermentation, often from corn. Cellulosic bioethanol is usually from a grass (switch grass)
    - *Biodiesel* from rapeseed and other sources

Biogas Production Processes

- **Biogas** is generated when bacteria degrade biological material in the absence of oxygen, in a process known as anaerobic digestion. Since **biogas** is a mixture of methane and carbon dioxide, it is a renewable fuel produced from waste treatment.
- Many microorganisms affect anaerobic digestion, including acetic acid-forming bacteria (acetogens) and methane-forming archaea (methanogens). These organisms promote a number of chemical processes in converting the biomass to biogas.
- The four key stages of anaerobic digestion involve hydrolysis, acidogenesis, acetogenesis and methanogenesis. The overall process can be described by the chemical reaction, where organic material such as glucose is biochemically digested into carbon dioxide (CO_2), 30-45% and methane (CH_4), 55-65%, traces of H_2S and water vapor by the anaerobic microorganisms.

$$C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4$$

- Advantages
  - Versatile
  - Renewable
- Disadvantages
  - Low energy density/yield
    - In some cases (eg, corn-derived bioethanol) may yield no net energy

Geothermal Energy

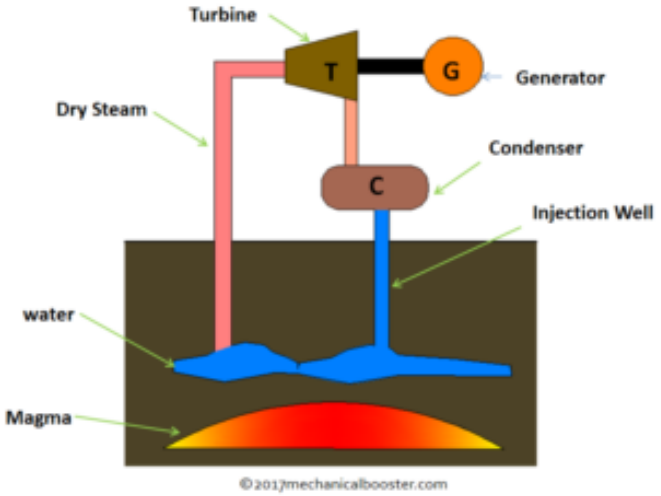
- How it works
  - Geothermal power plants
    - Use earth's heat to power steam turbines
  - Geothermal direct use
    - Use hot springs (etc) as heat source
  - Geothermal heat pumps
- Advantages
  - Renewable
  - Easy to exploit in some cases
  - CO_2 production less than with fossil fuels
  - High net energy yield
- Disadvantages
  - Not available everywhere
  - H_2S pollution
  - Produces some water pollution (somewhat similar to mining)

Working Principle of Geothermal Power Plant:

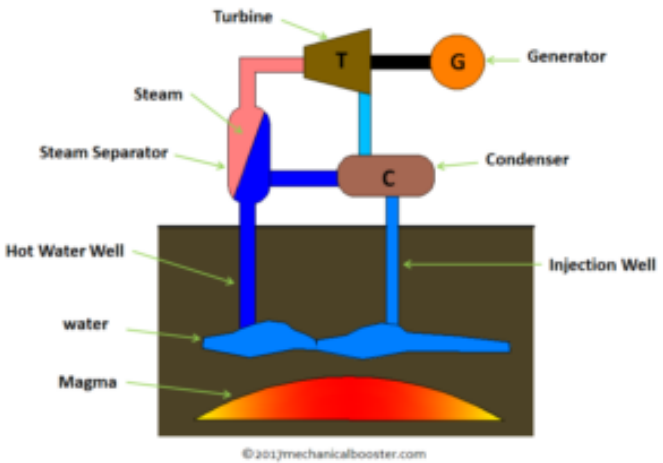
- The increase in temperature below the surface of earth is measured using geothermal gradient. Except near the tectonic plate boundaries it is about 25° C per km of depth.

- The magma heats the water present inside the earth and increases its temperature greater than 182 degree Celsius. This hot water from the earth is piping to the surface of the earth through hot water wells. The steam from the hot water is separated and made it to strike on the turbine blade and it starts rotating. A Generator is coupled to the turbine also starts rotating and produces electricity.

- In South America, Central America, Japan, Malaysia, Indonesia, and Philippine, Electricity generates from Geothermal Thermal energy.



Dry steam Geothermal Power plant



Flash Steam Geothermal Power plant

RENEWABLES

CURRENT STATUS OF GRID CONNECTED RENEWABLE ENERGY RESOURCES

- The JNNSM aims at adding 20,000 MW solar power capacity by 2022.

- The Ministry of New and Renewable Energy (MNRE) is envisaging a capacity addition of about 30,000 MW from renewable during 12th Plan

- The total installed capacity from renewable is 22447 MW (December 2011)

- A total installed capacity of 15880 MW of wind power
- Target of 15000 MW has been proposed for 12th plan.

- The cumulative biomass power /bagasse cogeneration based power capacity has reached 3056 MW.

- Global renewable energy annual capacity grew from 64.6 GW in 2010 to 75.6 GW in 2011

➢***Frequency Control:*** Frequency changes are the direct measurement of demand/supply balances. Drop in frequency means greater demand, vice-versa rises in frequency are indications of reductions of customer loads.

Conventionally frequency control is provided by fine tuning of hydro plants.

The problems due to intermittency come into effect only when the penetration level of intermittent sources goes above acceptable levels (usually 10% to 15% of the total energy production).

➢*Spinning reserves:* The spinning reserve is the extra generating capacity that is available by increasing the power output of generators that are already connected to the power grid. Such spinning reserves should be able to tolerate the unpredictable fluctuation in the renewable energy production.

➢***Peak loading:*** The wind and solar power systems have a very low production cost so these units will be the first to get connected to the grid and will help in reducing the requirement for the peaking power plants during the day time or during high wind speeds.

Piezoelectricity

- **Certain materials especially the crystalline ones, produce an emf when deformed by an application of pressure along the specific axis. This phenomena is known as piezoelectricity or piezoelectric effect.**
- **For details click in the below link.**

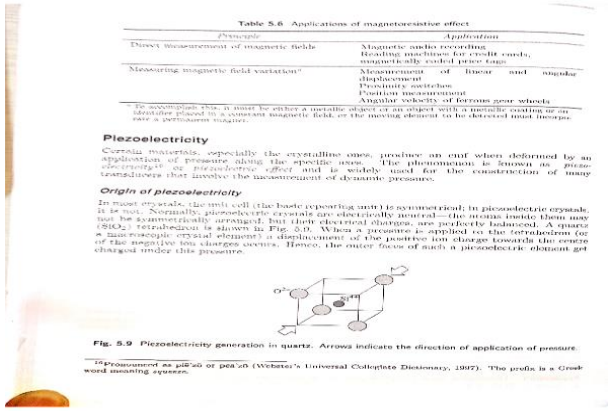


Table 5.6 Applications of magnetoresistive effect

Principle	*Application*
Direct measurement of magnetic fields	Magnetic audio recording Reading machines for credit cards, magnetically coded price tags
Measuring magnetic field variation*	Measurement of linear and angular displacement Proximity switches Position measurement Angular velocity of ferrous gear wheels

* To accomplish this, it must be either a metallic object or an object with a metallic coating or an armature placed in a constant magnetic field, or the moving element to be detected must incorporate a permanent magnet.

Piezoelectricity

Certain materials, especially the crystalline ones, produce an emf when deformed by an application of pressure along the specific axis. The phenomenon is known as *piezoelectricity*[14] or *piezoelectric effect* and is widely used for the construction of many transducers that involve the measurement of dynamic pressures.

Origin of piezoelectricity

In most crystals, the unit cell (the basic repeating unit) is symmetrical; in piezoelectric crystals, it is not. Normally, piezoelectric crystals are electrically neutral—the atoms inside them may not be symmetrically arranged, but their electrical charges are perfectly balanced. A quartz (SiO_2) tetrahedron is shown in Fig. 5.9. When a pressure is applied to the tetrahedron (or a macroscopic crystal element) a displacement of the positive ion charge towards the centre of the negative ion charges occurs. Hence, the outer faces of such a piezoelectric element get charged under this pressure.

Fig. 5.9 Piezoelectricity generation in quartz. Arrows indicate the direction of application of pressure.

[14]Pronounced as pīē'zō or pēā'zō (Webster's Universal Collegiate Dictionary, 1997). The prefix is a Greek word meaning *squeeze*.

Summary

- **The renewable sources are cost effective, user-friendly, so that they can easily beat the fossil fuels.**
- **By promoting renewable energy sources we can avoid, Air pollution, soil pollution and water pollution.**
- **Country's Economy will increase.**
- **Due to technological advancement vehicles are made with improved fuel efficiency and also perfect hybrid vehicle are made.**
- **Throughout the year these sources are available without affecting the Environment.**

Self Assessment Questions

- **Solve VU 2019 question.**
- **Write down working principle with necessary diagram of Solar Cell, Solar Water Heating System, Solar Cooker, Wind Turbine, Hydro electric Power generation, Geothermal Energy Harvesting and Biogas Plant.**
- **Name Five Hydroelectric Power Station India with their installed capacity.**
- **Write down the composition of Biogas.**
- **What is Photovoltaic Effect.**
- **Write down different types of Wind-turbine,**
- **Why solar water heating tubes were kept inside glass plates.**

Suggestions

- **For any quarry, mail to**

jotir_moy@yahoo.com or contact through mobile.

Thank You