Module -V

ENERGY SOURCES & STORAGE DEVICES

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5.1 Energy Sources- Introduction

Energy is an important criteria for the economic growth and wealth of a country. Natural resources are one of the resources that human consume to generate the energy. Nowadays utilization of energy sources has become very high and has led to unavoidable crisis. To handle this energy crisis, scientists are involving in finding new alternative energy resources, such as wind energy, solar energy, nuclear energy, etc. These energy sources are continuous and will not exhaust at all. Nuclear energy is an unique energy source that produces exceptionally high amount of energy than the conventional energy sources.

Though the energies are produced, storage of such energy is a very difficult task. Hence storage devices are extremely important.

5.1.1 Nuclear Energy

The energy released during the fission or fusion reaction is known as nuclear energy.

Uses of nuclear energy

1. To generate electricity.
2. Treatment of diseases like cancer.
3. In improvement of agriculture and industry.

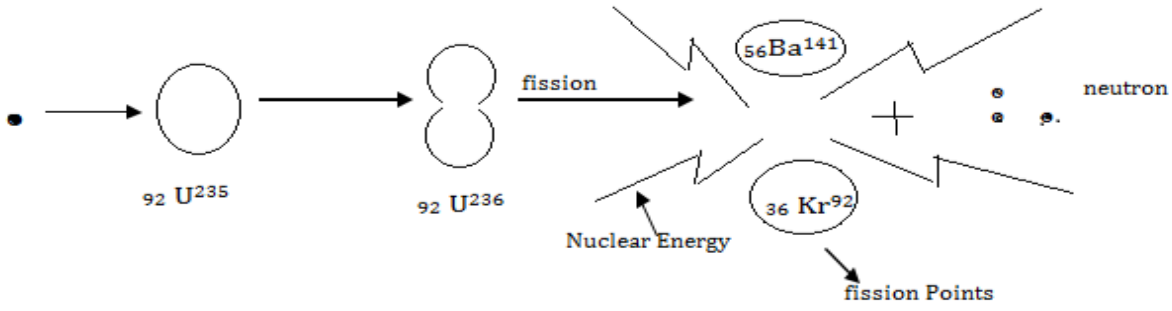
5.1.2 Nuclear Fission

The process of splitting of heavier nucleus in to 2 or more smaller nuclei with the release of huge amount of energy is called nuclear fission.

Example

$$_{92}U^{235} + {}_{0}n^{1} \longrightarrow {}_{92}U^{236} \longrightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + {}_{30}n^{1} + E$$

The above reaction can be illustrated as below,



How is energy released during nuclear fission reaction?

In fission reaction,

The sum of masses of the products < the total mass of the reactants. This loss in mass is converted into energy by Einstein's equation, $E = mc^2$, where E= energy, M= loss in mass, C= velocity of light.

Calculation of energy released during the fission of $_{92}U^{235}$

The fission reaction is,

$$\underbrace{{}_{92}U^{235} + {}_{0}n^{1}}_{\text{reactants}} \longrightarrow \underbrace{{}_{56}Ba^{141} + {}_{36}Kr^{92} + {}_{30}n^{1} + \text{Energy}}_{\text{Products}}$$

Total Mass of Reactants			Total Mass of Products		
mass of $_{92}U^{235}$	=	235.120	mass of $_{56}Ba^{141}$	=	140.910
mass of $_{0}n^{1}$	=	1.009	mass of $_{36}Kr^{92}$	=	91.910
Total mass of reactants	=	236.129 amu	mass of $3_{0}n^{1}$ (3x1.009)	=	3.027
			Total mass of products	=	235.847 amu

Loss in mass (mass defect) = Total mass of reactants – Total mass of products

= 236.129 - 235.847

0.282 amu

1 amu = 931 MeV

Therefore, 0.282 amu = 0.282 x 931 MeV = 262.524 MeV

5.1.3 Characteristics of nuclear fission

1) Thermal neutrons are use to split the heavier nucleus of U-235.
2) Heavier nucleus splits into 2 or more small nuclei.
3) Two or more neutrons are released.
4) Large amount of energy is released.
5) All the fission products are radioactive, giving off β and γ radiations.
6) Atomic weight of the fission fragments ranges from 70 to 160.
7) The fission reactions are self-propagating.
8) Nuclear fission reactions can be controlled by absorbing the extra neutrons.
9) All the neutrons released in the fission reaction need not hit the nucleus, but it may escape into the atmosphere.
10) The number of neutrons released per single fission is called the multiplication factor. If it is less than 1, there is no chain reaction.

5.1.4 Types of nuclear fission reactions

There are two types nuclear fission reactions,

1. Controlled nuclear fision reactions
2. Uncontrolled nuclear fission reactions

1. Controlled nuclear fission (Controlled chain reaction)

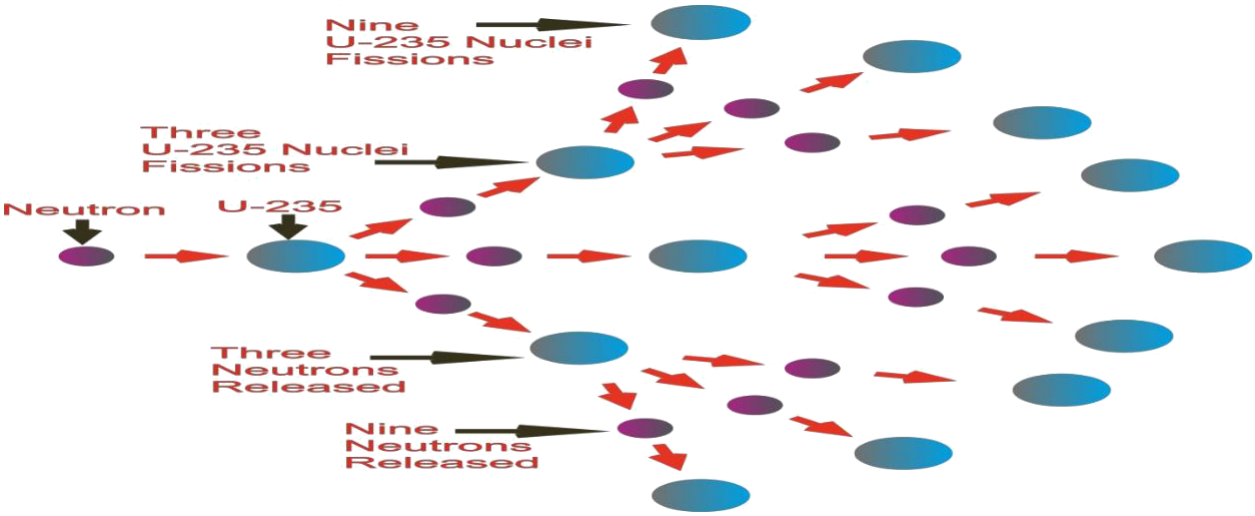
The nuclear fission reaction carried out in a nuclear reactor can be controlled by absorbing the desired number of neutrons. Only one neutron is allowed to continue the fission reaction. The energy released in such reactions can be utilized for many constructive purposes. Example: Atomic power station

2. Uncontrolled nuclear fission reaction

Here the nuclear fission reaction occurs in a random manner. The energy released causes huge damage to life and property. All the neutrons are involved in the reaction. Example: Atom bomb

5.1.5 Nuclear Chain reactions

A fission reaction in which the neutrons from the previous step continue to propogate and repeat the reaction is termed as nuclear chain reaction.



5.1.6 Criteria for nuclear chain reaction to occur

1. For a nuclear chain reaction to occur, sufficient amount of fissionable material should be present.
    - **Critical mass** is the minimum mass of fissionable material required to carry out the nuclear chain reaction.
    - **Sub- critical mass**

      If the mass of the fissionable material is less than the critical mass, it is called sub- critical mass.
    - **Super critical mass**

      If the mass of the fissionable material is more than the critical mass, it is called super-critical mass.
2. The mass greater or lesser than the critical mass will hinder the propagation of the nuclear chain reaction.

5.1.7 Nuclear fusion

Nuclear fusion is the process in which 2 or more smaller nuclei combine to give one heavier nucleus with the simultaneous release of huge amount of energy. Nuclear fusion reaction takes place at very high temperatures (near the sun).

Example:

$$_1H^2 + {}_1H^2 \xrightarrow{\text{near sun}} {}_2He^4 + \text{Energy}$$

2 hydrogen nuclei — helium nucleus

5.1.8 Characteristics of nuclear fusion reaction

a. The nuclear fusion reaction is possible only when the distance between the nuclei is one Fermi.
b. Only lighter nuclei can undergo nuclear fusion reaction.
c. The energy required for the fusion reaction to occur is very high (100 million Kelvin).
d. The amount of energy released during a fusion reaction is four times greater than that of a fission reaction.

5.1.9 Differences between nuclear fission and nuclear fusion

Sl.No	Nuclear Fission	Nuclear Fusion
1	Splitting of heavy nucleus into smaller nuclei.	Small nuclei combine to form heavier nucleus.
2	Emits neutrons.	Emits positrons.
3	Occurs at ordinary temperature.	Occurs at very high temperatures (> 10^6 k)
4	Can be controlled.	Cannot be controlled.
5	It is a chain process.	It is not a chain process.
6	Fission products are radioactive.	Fusion products are not radioactive.
7	Energy released is less when compared to nuclear fusion reactions	Very high amount of energy is released.
8	Controlled nuclear fission occurs in a nuclear reactor.	Occurs near the sun.

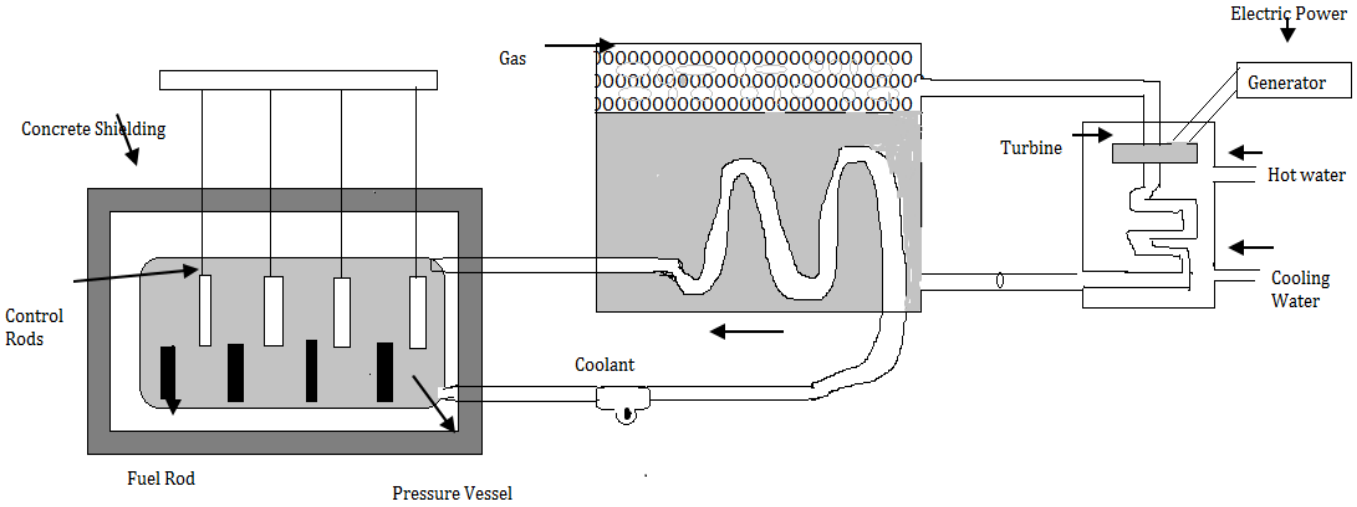
5.1.10 Nuclear Reactor (Or) Nuclear Pile

Definition

Equipment in which the nuclear fission reaction takes place in a controlled manner is known as a nuclear reactor.

5.1.11 Light water Nuclear Power Plant (or) Light water nuclear Reactor

It is a nuclear reactor in which the fuel rods are submerged in water. Ordinary water acts as coolant & moderator. It is used to produce electricity.



5.1.12 Components of a Nuclear reactor

The main components of a light water nuclear reactor are as follows,

1. Reactor core
2. Fuel rods
3. Control rods
4. Moderator
5. Coolants
6. Pressure vessel
7. Protective shield
8. Heat exchanger
9. Turbine

1. Reactor core

It is a part of the nuclear reactor in which controlled nuclear fission reaction takes place. It consists of the fuel rods, moderator, coolant and control rods. It is a circular cylinder with a diameter ranging from 5 to 15m.

2. Fuel rods

U^{235} rods are used as fuel. It produces heat energy and neutrons to start the nuclear chain reaction.

3. Controls rods

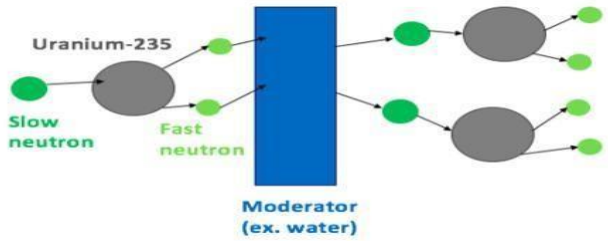
- Controls rods are used to control the fission reaction. They are hung in-between the fuel rods.
- Cadmium (or) Boron rods are used as control rods.
- Control rods absorb the extra neutrons and control the fission reaction.

$$^{10}_{5}B + {}^{1}_{0}n \longrightarrow {}^{11}_{5}B + \text{gamma ray}$$

$$^{113}_{48}Cd + {}^{1}_{0}n \longrightarrow {}^{114}_{48}Cd + \text{gamma ray}$$

4. Moderators

- Moderators are used to slow down the neutrons. The kinetic energy of the neutrons is reduced from 1 MeV to 0.25 eV.
- In light water nuclear reactor ordinary water is used as moderator.
- Heavy water, Graphite, Beryllium can also be used as moderator.



Coolant

- Coolant absorbs the heat energy from the reaction core.
- It enters through the base of the reactor and comes out through the top.
- Ordinary water is used as coolant in Light water nuclear reactor.
- Heavy water, liquid Na or K can also be used as coolants.

5. Pressure vessel

- The reaction core is surrounded by the pressure vessel.
- It provides entry and exit path for the coolant.
- It can withstand a pressure of 200kg/cm^2.

6. **Protective shield**

- The reactor core is covered by a 10 m thick concrete wall.
- It protects the environment from the harmful radioactive emissions.

7. Heat Exchanger

- Heat exchanger contains water.
- The coolant transfers the heat to the water kept in the heat exchanger and produces steam.

8. Turbine

- The steam produced in the heat exchanger is used to operate a turbine which in turn drives a generator to produce electricity.

Working

- The fission reaction is started in the reaction core and controlled by using control rods.
- The heat released by the fission of U^{235} is absorbed by coolant (ordinary water)
- The heat from coolant is transferred to the heat exchanger containing water and water is converted to steam.
- Steam drives the turbine to generate electricity.

5.1.1 Breeder Reactor

Reactor which converts non fissionable (fertile material) into fissionable material (fissile material) is known as Breeder reactor.

Fertile material (non fissionable) – (U^{238}, Th^{232} eg)

Fissile Material (fissionable) - (U^{235}, Pu^{239} eg)

In a breeder reactor,

$$_{92}U^{238} + {}_{0}n^{1} \longrightarrow {}_{94}Pu^{239} + 2\,{}_{-1}e^{0}$$

(non –fissionable) (fissionable)

$$_{94}Pu^{239} + {}_{0}n^{1} \longrightarrow \text{fission products} + 3{}_{0}n^{1}$$

- Here U^{238} is known as the primary fuel.
- Pu^{239} is known as the secondary fuel.

Working

In a breedor reactor, three neutrons are emitted in the fission of U-235. Only one neutron is used for continuing the reaction with U-235. The other two neutrons are allowed to react with U-238. Hence, two Pu-239 atoms are produced for each atom of U-235 consumed.

- **Conversion factor = No.of 2_o fuel atoms produced / No.of 1_o fuel atoms consumed**

- For a breeder reactor, the conversion factor is greater than one.

5.1.14 Solar energy conversion

Solar energy conversion is the process of conversion of direct sun light into a more useful form of energy. The solar energy conversion takes place through the following ways,

1. Thermal conversion
2. VPhoto conversion

1. Thermal conversion

This involves the absorption of thermal energy in the form of IR radiation.

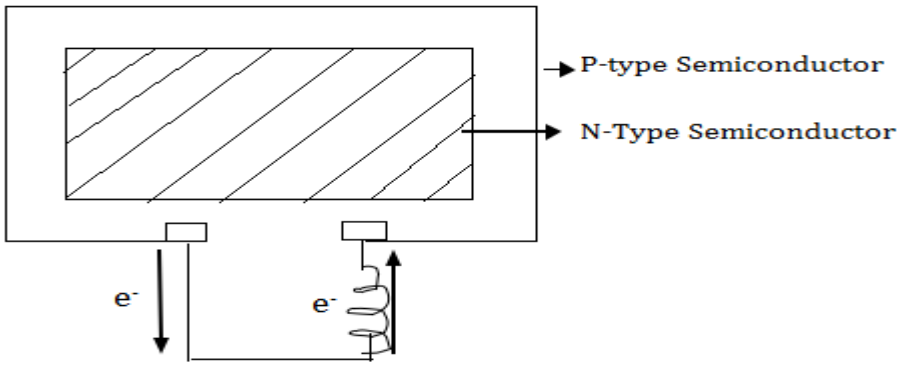
Examples: Solar cooker, solar heat collector and solar water heaters.

2. Photo conversion

This involves the conversion of light energy directly into electrical energy by photoelectric effect. Photo conversion may be carried out by using a photo galvanic cell or solar cell.

5.1.15 Solar Cells

- Devices that convert solar energy into electrical energy are known as solar cells.
- They make use of photovoltaic effect.
- So solar cells can be otherwise called as photovoltaic cells.



Description

- Solar cells consist of a p-type semiconductor and n-type semiconductor kept in close contact with each other.

- When solar rays fall on the p-type semiconductor the electrons jump from valance band to conduction band. Thus they cross the p-n junction and go to the n-type semiconductor.
- This causes a potential difference between the two laters, which causes the flow of electrons. Because of this current is produced.

Uses

- Solar cells are used in calculator , electronic watches etc,.
- Solar Batteries are used to run street lights, water pumps, radio and television.
- It is power source in spacecraft and satellites.

Advantages

- Solar cell is ecofriendly.
- It is a pollution free source.

Disadvantages

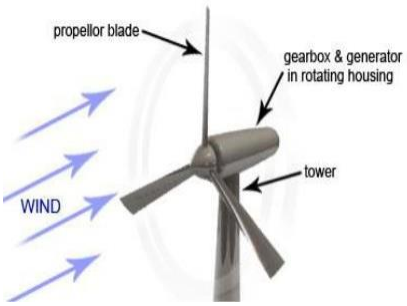
- Huge capital cost is required for installation.
- It can not be used when sunlight is not available.
- It produces DC voltage.
- During night and rainny days alternate source of electricity is required.

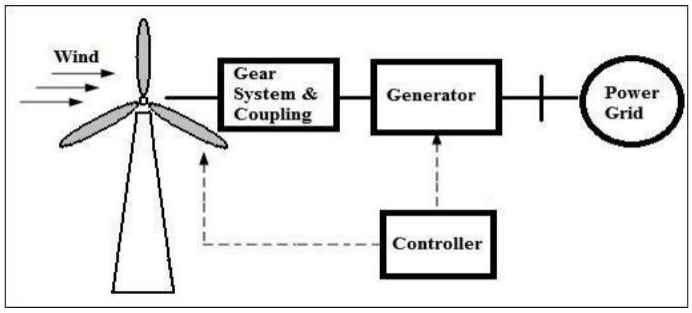
5.1.16 Wind Energy

- Air in motion is called wind. Energy got from the force of wind is called wind energy.
- Wind energy is collected by using wind mills.
- Wind mill is a device used to produce electricity from wind.

Working of wind mill

- The blowing wind strikes the blades of the windmill and makes it to rotate.
- Here, kinetic energy of wind is converted to mechanical energy.
- The rotating blade drivers a generator to produce electricity.
- Here, the mechanical energy is conerted into electrical energy.





Advantages

- Wind energy is a renewable and inexhaustible energy source. It is a eco- friendly source.
- It can be built onshore or offshore.
- It can be used to supply power to remote and rural areas.

Disadvantages

- It creates a mild noise pollution. The installation cost is high
- It affects the migratory path of the birds