CMR INSTITUTE OF TECHNOLOGY	USN										

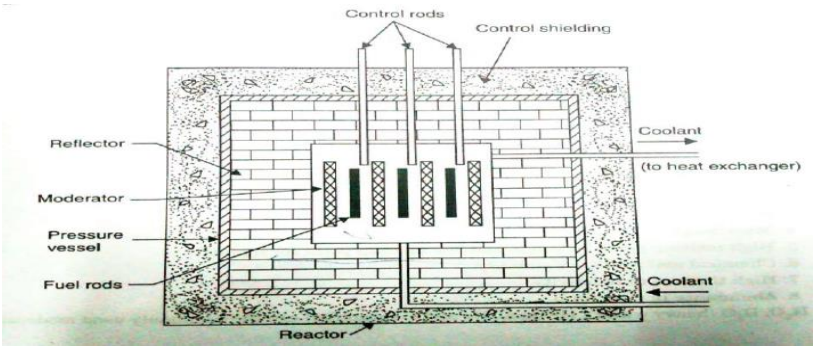
Internal Assesment Test II – August 2022									
Sub:	POWER GENERATION AND ECONOMICS							Code:	18EE42
Date:	26/08/2022	Duration:	90 mins	Max Marks:	50	Sem:	IV	Section:	A

Note: Answer any **FIVE FULL** Questions
Sketch neat figures wherever necessary. Answer to the point. **Good luck!**

		Marks	OBE CO	OBE RBT
1	Explain the function of moderator, control rod and coolant in Nuclear power plant	[10]	CO2	L2
2	What are the classification of Nuclear reactors? Explain the operation of Fast Breeder Reactor	[10]	CO2	L2
3	Explain the working of Heavy water cooled and moderated(CANDU Reactor)	[10]	CO2	L1
4(a)	Explain the various methods of nuclear waste disposal	[10]	CO2	L2
4(b)	What is a protective relay? Explain its function in an Electrical System	[10]	CO3	L2
5	With a neat diagram, explain the working of HRC(High Rupturing Capacity) fuse	[5]	CO3	L2
6	Draw and explain the Layout of Duplicate Bus bar system	[5]	CO4	L1
7	Explain the following : (a)fixed cost (b)Semi - fixed cost (c)Running or Operating cost in power plants	[10]	CO5	L2
8	What are the different methods of determination of depreciation? Explain the Straight line method	[10]	CO5	

Solution of PGE IAT3

1. Function of Moderator, control rod and Coolant



Moderator

- The purpose of moderator is to slow down the fast moving secondary neutrons, so that chain reaction is sustained.
- The moderator surrounds the fuel rods.
- As soon as fast moving neutrons are given out, as a result of chain reaction they collide against the moderator and slow down.
- They are now capable of causing further fission, and thus the chain reaction continues.
- Materials used as moderators are ordinary water, heavy water, beryllium and graphite.
- Moderator should have high scattering cross section and low neutron absorption cross section

Control Rods

- Control rods are meant for controlling the rate of fission of U 235.
- Control rods are rods, plates, or tubes containing a neutron absorbing material which are made of boron, cadmium etc, that absorb some of the slowed neutrons.
- In a reactor, nuclear chain reaction has to be initiated when started from cold, and the chain reaction is to be maintained at a steady value during the operation of reactor.
- Also the reactor must be able to shut down automatically under emergency conditions.
- All this requires a control of reactor so as to prevent the melting of fuel rods, disintegration of coolant & destruction of reactor, the release of energy is enormous.

Coolant

- It is a medium through which the heat generated in the reactor is transferred to the heat generator for further utilization of power generation.
- If water is used as coolant it takes up heat & gets converted into steam in the reactor which is directly used for driving the turbine.
- A good coolant should not absorb neutrons, should be non oxidising, non toxic & non corrosive and have high chemical and radiation stability and good heat transferrability.
- Gases : Air, helium, hydrogen & CO2
- Liquids : Light & heavy water.
- Metals : Molten sodium & Lithium are used as coolants.

2. Classification of Nuclear Reactors

- Nuclear reactors may be classified in several ways i.e on basis of their applications, type of fission, fuel used, state of fuel, fuel cycle, arrangement of fuel and moderator, moderator material, cooling employed, coolant used etc.

❑ According to the application

▪ Research and Development Reactors

➢ These reactors are used for testing new reactor designs and research.

- Production

➢ For converting fertile materials into fissile materials.

- Power

➢ These reactors are used for generation of electrical energy.

❑ According to type of fission

- Slow reactors

➢ Neutron kinetic energy is less than 0.1 eV

- Intermediate reactors

➢ Neutron kinetic energy is between 0.1 eV and 0.1 MeV

- Fast neutron

➢ Neutron kinetic energy 1 MeV or more.

- According to type of fuel used
  - ➢ Natural uranium
  - ➢ Enriched uranium
  - ➢ Plutonium
- According to state of fuel
  - ➢ Solid
  - ➢ Liquid
- ❑ According to fuel cycle
  - Burner reactor
    - ➢ Designed for producing heat only without any recovery of converted fertile material.
  - **Converter reactor**
    - ➢ Such reactors convert fertile material into fissile material different from the one initially fed into the reactor core.
  - **Breeder reactor**
    - ➢ Such reactors convert fertile material into fissile material, which is similar to one initially supplied to the reactor core.
    - ➢ A breeder reactor is also which convert fertile material into fissile material at a higher value thanat which the fissile material is consumed.
  - Arrangement of fissile and fertile material
  - One region
  - Fissile and fertile material mixed
  - Two region
  - Fissile and fertile material separated
- ❑ Arrangement of fuel and moderator
  - Homogeneous reactor

- Nuclear fuel and moderator represent uniform mixture in the fluid form, including gases, liquids and slurries (mixture of an insoluble substance, as cement, clay with liquid)

- **Heterogeneous reactor**

Separate fuel rods are inserted in the moderator in some sort of regular arrangement forming a so called lattice.

- Moderator material
  - Heavy water
  - Graphite
  - Ordinary water
  - Beryllium
  - Organic reactors
- On basis of coolant used
  - Gas
  - Water
  - Heavy water
  - Liquid metal reactors
- On basis of cooling system
  - Direct

- The liquid fuel circulated from the reactor to heat exchanger where steam is generated.

- **Indirect**

- Coolant passed through the reactor and then through the heat exchanger for steam generation

- Power reactors in common use
- Boiling Water Reactor
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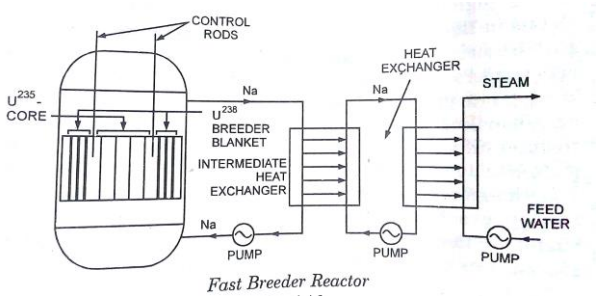
- pressurized Water Reactor
- Gas Cooled Reactor
- Heavy Water Cooled and Moderated (CANDU TYPE) Reactor
- Liquid Metal Cooled Reactors
- Fast Breeder Reactor

Fast Breeder Reactor



Fast Breeder Reactor

- A fast breeder reactor is a small vessel in which the required quantity of **enriched uraniumor plutonium is kept without a moderator.**
- The fissionable fuel core is surrounded by a blanket of fertile material (U 238 or Th 232)
- **The fertile material absorbs neutrons produced by the fissioning of U 235 and produces fissile material Pu239 or U233 respectively**.
- Two heat exchangers are used.
- The reactor core is cooled by liquid metal.
- In the second heat exchanger the coolant is **again liquid sodium/ potassium which transfer heat to feed water to generate steam**

3. CANDU Reactor

The word **CANDU stands for Canadian Deuterium Uranium**.

- These r**eactors make use heavywater composed of the heavy hydrogen isotope**, as moderator to have maximum neutron economy and as coolant also.
- It is used in countries where **enriched uranium is not available**.
- The primary and secondary circuits are similar to PWR.
- The coolant heavywater is circulated in the primary circuit and the steam is produced in secondary circuit is transferring the heat in the heat exchanger.

Advantages

- Simpler reactor control because absence of fuel rods.
- Low fuel consumption.
- More effective in slowing down the neutrons because moderator being at low temperature.

- **Disadvantages**

- Heavy cost of heavy water

Very high standard design.

4(a)Methods of nuclear waste disposal

- Solid radioactive wastes arise from used filters, sludge from the cooling ponds, pieces of discarded fuel element cans, splitters etc.
- These discarded items of plants such as control rods have to be stored on site in **shielded concrete vaults.**
- The storing in shielded storage vaults consists of fixing the solid waste in **borosilicate glass and then storage of this glass in leak tight capsules.**
- These capsules or vaults cab then be stored in deep salt mines or in deep wells drilled in the stable ocean floor.
- Sometimes, **suitable containers are filled with radioactive waste and sunk to the bottom of seas and oceans.**
- Another way of disposal is the **separation and transmutation of the long lived isotopes to short-lived or stable products following neutron absorption in a breeder or fusion reactor.**
- It is safe enough to store radioactive waste underground in liquid form in suitable tanks or in reduction to clinker (Stony residue)
- Clinkering serves a two fold purpose of improving the protection and reducing the volume of waste.
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- One more method is "**solidifying**" the liquid radioactive waste through heat up and evaporation.
- Gaseous effluents are filtered before discharging into atmosphere. Moreover, the filtered gas is discharged at high levels so that it is dispersed properly.
- The probability of fire in the reactor fuel channel is extremely low. However, if fire breaks out, large volumes of gaseous fission products may be released.
- So it is necessary to have a **clean up plant through which these products can be passed for removal of radioactive iodine which is the main hazard.**

4(b)Protective relay and its function

Protective relays were discovered more than 150 years ago. The switchgear is capable of detecting any fault in the electrical system. The relay can guide the circuit breaker so that any defective element is isolated in the system. A protective relay can be installed in the electrical system to keep track of the abnormal conditions in the circuits. It can measure the electrical configuration and can find out whether the system has faulty or normal conditions. Some of the variables of an electric system may include frequency, voltage, current, impedance, and phase angles. When a variable changes in its measurement,

the signal of a fault is sent to the protective relays along with its location and type. Once a **protection relay** detects a fault, it will operate automatically and will close down the breaker's trip circuit. This way the faulty circuit will be disconnected from the system and the circuit breaker will be open.

Types of Protection Relays
There are different kinds of protection relays available. The important and most common types of protection relays include:

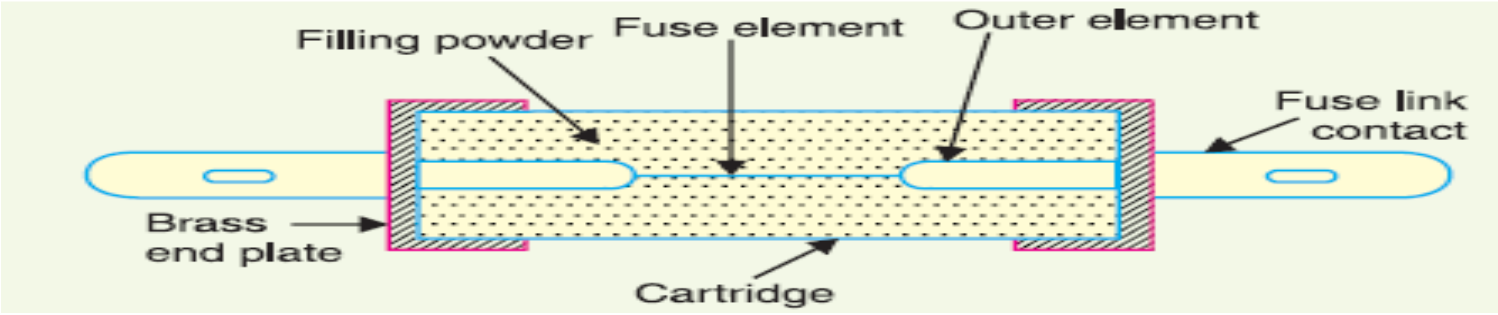
Overcurrent Relays
The overcurrent relays may get actuated through the current. The relay has a pick-up value and may start to operate when the current measurement and quantity exceed that value. The two types of relays commonly available in the market may include the time relay and the instantaneous relay types.

Most often, the relay system may contain both of these relays. One drawback of an overcurrent relay can be that it may also pick the current fluctuations and the faults in the adjacent zones.

Electromechanical relays
The electromagnetic relays are the earliest created relays that are still in use today in many places. An electromechanical protective relay can typically manage a maximum of two performance parameters or protective functions. The more complex varieties of the electromechanical relays (that may function based on the changes in electric electromagnetic forces) may be available as well.

5 . Working of HRC Fuse

- It consists of a heat resisting ceramic body having metal end-caps to which is welded silver current-carrying element.
- The space within the body surrounding the element is completely packed with a filling powder.
- The filling material may be chalk, plaster of paris, quartz or marble dust and acts as an arc quenching and cooling medium.
- Under normal load conditions, the fuse element is at a temperature below its melting point. Therefore, it carries the normal current without overheating.
- When a fault occurs, the current increases and the fuse element melts before the fault current reaches its first peak.
    - The heat produced in the process vaporizes the melted silver element.



6 Duplicate Busbar system

This system consists of two bus – bars :

(1)a main bus – bar

(2)a spare bus - bar

- Each bus-bar has the capacity to take up the entire sub-station load
- The incoming and outgoing lines can be connected to either bus-bar with the help of a bus-bar coupler which consists of a circuit breaker and isolators

- Ordinarily, the incoming and outgoing lines remain connected to the main bus-bar
- But in the case of repair of main bus-bar or fault occuring on it, the continuity of supply to the circuit can be maintained by transferring it to the spare bus-bar
- For voltages exceeding 33 kV, duplicate bus-bar system is frequently used
- The figure shows the arrangement of duplicate bus-bar system in a typical sub-station
- The two 66 kV incoming lines can be connected to either bus-bar by a bus-bar coupler
- The two 11 kV outgoing lines are connected to the bus-bars through transformers (66 / 11 kV) and circuit breakers

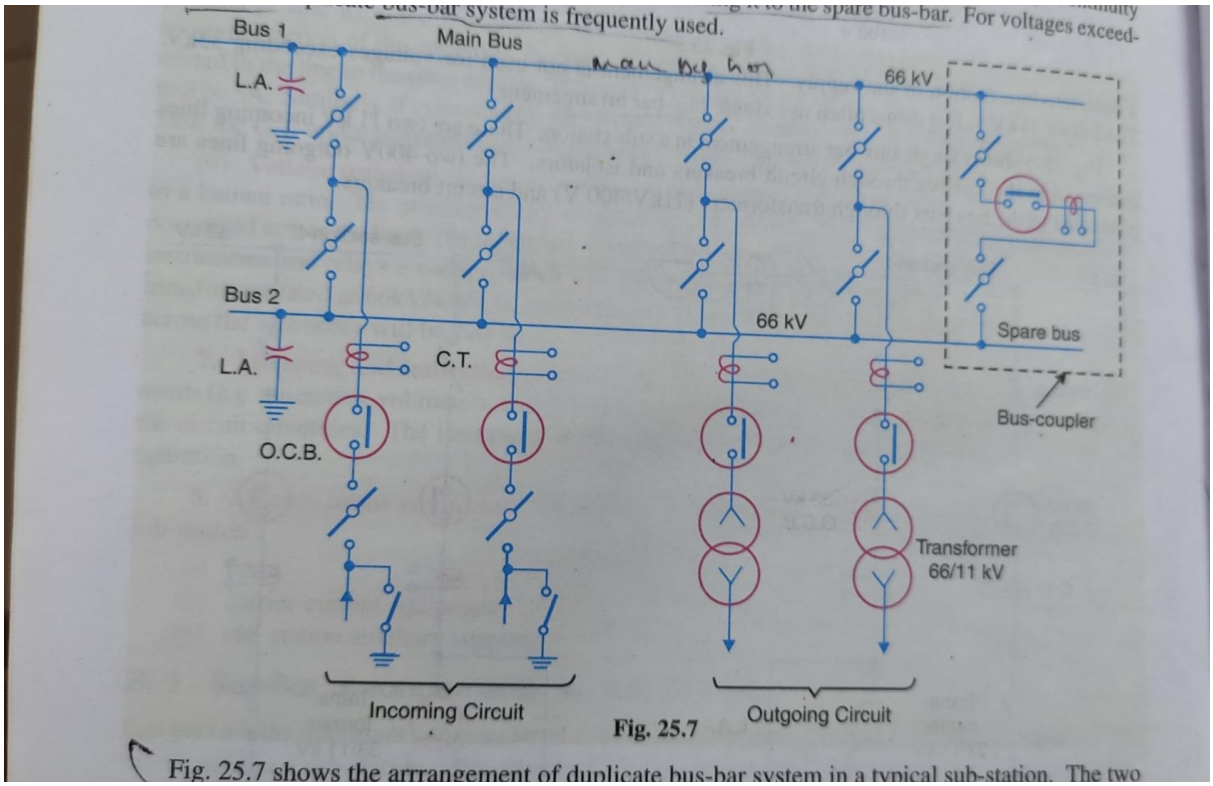


Fig. 25.7

Fig. 25.7 shows the arrrangement of duplicate bus-bar system in a typical sub-station. The two

7 Fixed cost, semi fixed cost and operating cost

- ❖ Fixed cost
  - ➢ This cost is independent of maximum demand and energy output.
  - ➢ It is due to the annual cost of organization, interest on the capital of land and salaries of high officials.
  - ➢ The annual expenditure on central organisation and salaries of high officials is fixed since it has to meet whether the plant has high or low maximum demand or it generates less or more energy.

- Further, the capital investment on the land is fixed and hence the amount of interest is also fixed.

❖ Semi fixed Cost

- The cost depends upon the maximum demand but is independent of energy output.
- The semi fixed cost is due to annual interest and depreciation on the capital cost of the generating plant, transmission and distribution network, buildings & other civil works, all types of taxes, insurance charges & salaries of management & clerical staff.
- Also yearly compensation given to workers is included under this head.
- The semi fixed cost is approximately proportional to maximum demand.
- The size and cost of the installation is governed by the maximum demand on the power plant.
- The greater the maximum demand on power plant, the greater is its size and cost of installation. further taxes, insurance charges & strength of clerical staff depend upon the size of the plant and hence upon the maximum demand.

Running or operating cost

- This cost depends upon the number of hours the plant is in operation or upon the number of units of electrical energy is generated.
- The running or operating cost is due to annual cost of fuel, lubricating oil, water, maintenance and repair cost of equipment and wages and salaries of operational and maintenance staff and salaries of supervisory staff engaged in the running of the plant.
- The operating cost is approximately proportional to units generated.
- Total annual cost incurred in the power generation is represented by

E = a + b kW+ c KWh Where a, b and c are constants.

8 Straight line method of determining depreciation

- Depreciation is the most important item in the fixed costs and it represents the reduction in the value of equipment and other property of the plant every year due to continuous wear and tear.
- This can be reduced by proper maintenance of the equipment and the buildings
- To account for the depreciation, a certain fixed amount is set aside every year so that by the time the life span of the plant is over, the total amount accumulated equals replacement cost
- Methods commonly used for determination of annual depreciation charges are
- Straight line method
- Diminishing value method
- Sinking fund method

❖ Straight Line Method

- This method assumes that certain **depreciation occurs according to the straight li**
- In this method a constant depreciation charge is made every year on the ba